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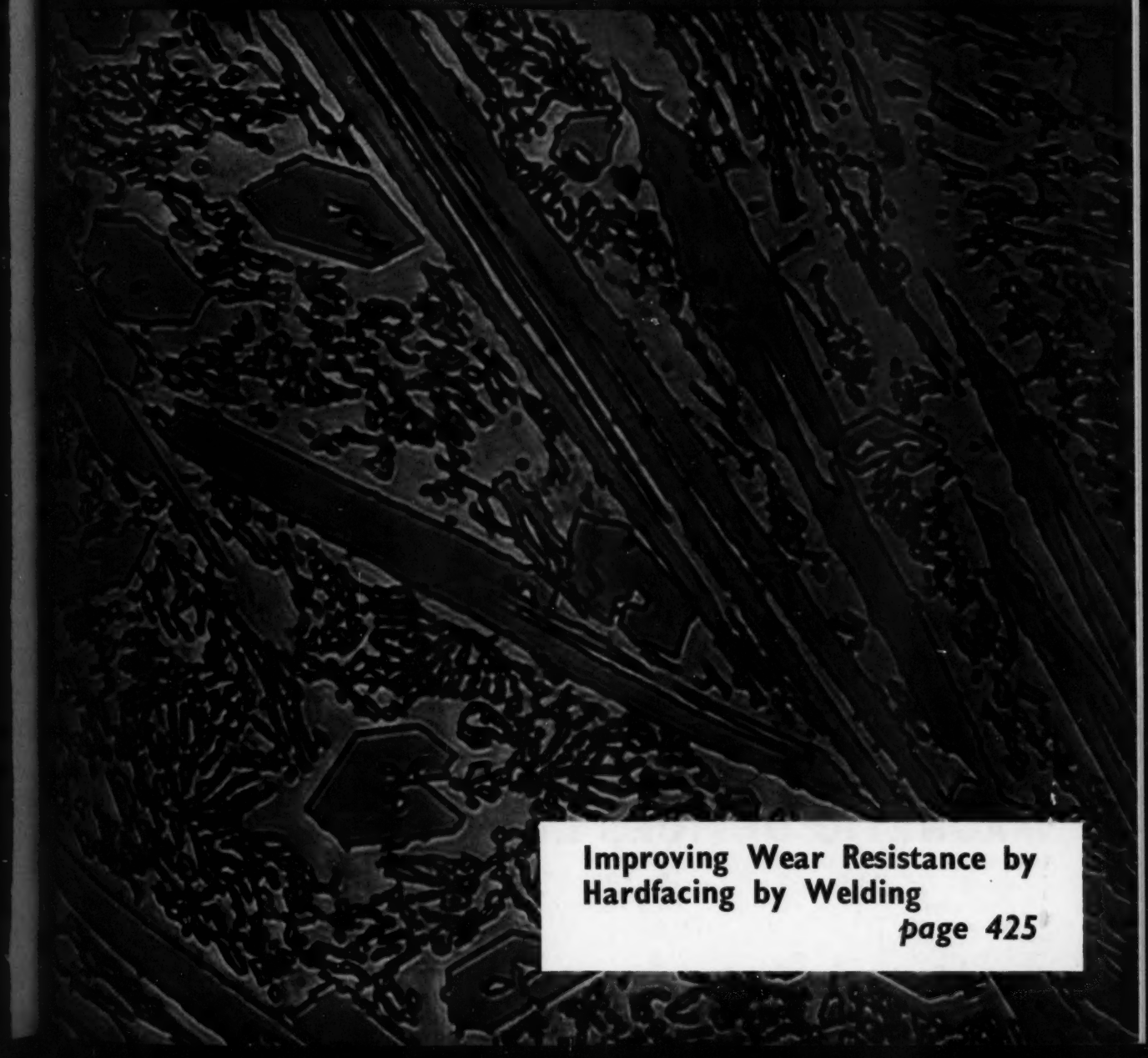

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Engineering Materials and Design

★ *The Magazine for Engineering Designers*

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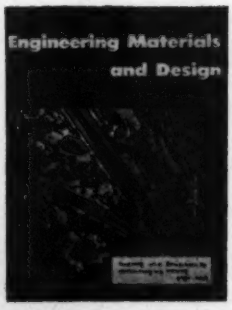

COVER — High chromium austenitic iron weld deposit showing hexagonal chromium carbides and smaller carbides in matrix of austenite. Mag. ×350, enlarged ×4 for reproduction. (Photo: Murex Welding Processes Ltd.)

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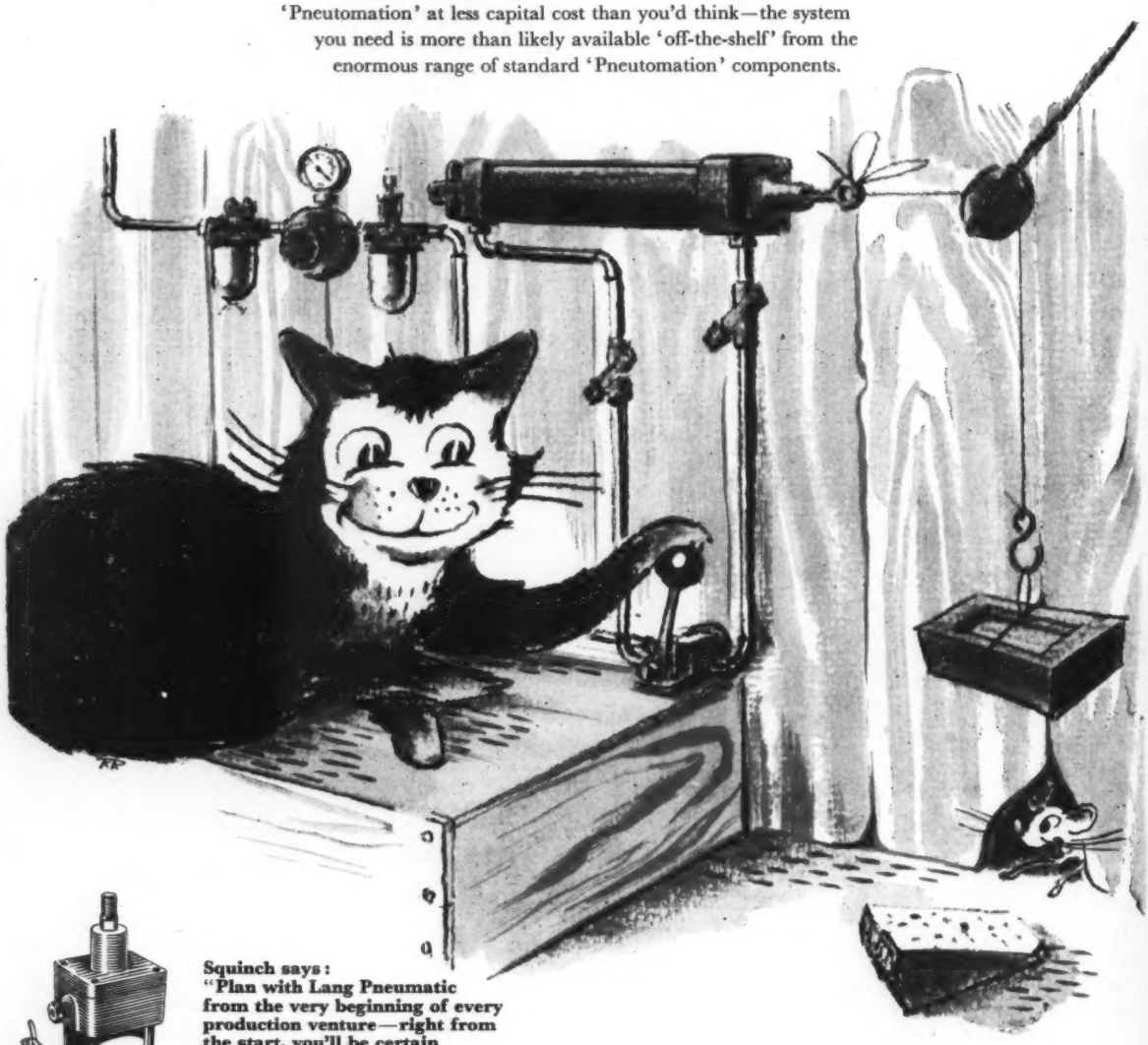

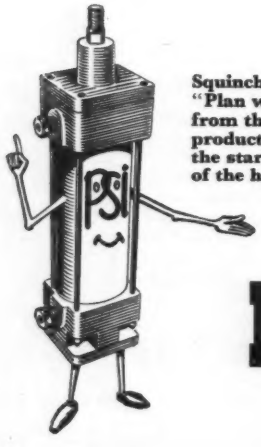

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MATERIALS IN THE NEWS

Monthly Digest of Materials and Design News from Home and Abroad

Beryllium's Other Uses

THE ATOMIC WEAPONS RESEARCH ESTABLISHMENT at Aldermaston recently admitted press representatives for the first time to its nuclear physics research division, which is devoted to the fundamental studies necessary for both military and peaceful uses. One of the points stressed by Sir William Penney on this occasion is that international barriers are fast disappearing on basic work in nuclear physics, while commercial barriers of secrecy are increasing.

One of the functions of the A.W.R.E. is metallurgical research. Beryllium is one of the important materials being studied, not only because of its nuclear characteristics but because it has a future potential in certain structural applications. Apart from specialised manipulations such as tube drawing, the plant is able to cope with all other major operations such as sintering, cold compressing, sandwich rolling and ingot casting. A good deal of effort has been expended on welding techniques for beryllium, the two main processes being argon arc and electron beam welding, the latter tending to have more success metallurgically but is less suited to production runs. Effort is also directed to improving the ductility and directional properties of the metal.

Interesting work with beryllium—which has been found to increase considerably the oxidation resistance of magnesium alloys—has also been carried out recently by Soviet scientists. Addition of amounts as small as 0.05 per cent by weight effect a definite improvement, while amounts of 0.1-0.2 per cent by weight give improvement of several hundredfold up to melting point. The difficulty is to obtain the solubility of the beryllium in magnesium, but this is claimed to have been overcome by an evaporation process, and a beryllium content up to 10 per cent has been obtained. When used for canning uranium fuel rods which swell and wrinkle under irradiation, the magnesium alloy will plastically deform but will give, in spite of this, complete protection.

Plastics Exhibition in Retrospect

THE EQUIPMENT SECTION of the recent International Plastics Exhibition at Olympia proved to be one of the most impressive aspects of the exhibition, since it contained much plant of advanced design. The overall appearance and compactness of many of the new machines showed that much attention was paid to these factors in the initial conception of their design, and a further welcome trend is the emphasis on easy servicing.

Vacuum moulding is another field in which noticeable advances have been made in recent years and the use of automatic machines for forming sheet materials promises to extend the applications of this very useful technique.

Apart from the development of polyolefins, which have already been mentioned in these columns, great interest is being shown in the fluorine-containing polymers, of which p.t.f.e. is the best known. The remarkable properties of this material in its resistance to corrosion and high temperature as well as its non-stick property have led to its successful introduction in many branches of industry. Further developments in which fluorine is used to replace hydrogen in the polymer structure promise to make available materials which are easier to work.

Production of plastics in the U.K. continues to rise. Total output here just before the war was less than 30,000 tons a year; it now tops the 400,000 tons mark.

Underground Rocket

THE FIRST UNDERGROUND ROCKET is reported to have been developed in the Soviet Union; it is being used to dig tunnels. The first part of the rocket has a pulverising device which contains liquid fuel and compressed air. Powerful flames spout from openings in the pulveriser, opening a path for the rocket in a pre-determined direction. In this way, a cylinder-like tunnel develops behind the rocket.

The first experiments are said to have produced satisfactory results. In the future, the device will be used to lay underground irrigation canals and pipes.

Air—an Engineering Material

ONE OF THE MOST INTERESTING trends in the development of engineering equipment is the growing importance of air for the transmission of power and for supporting loads. It is perhaps surprising that air was not commercially exploited on a large scale years ago, in view of its super-abundance, low cost and almost frictionless characteristics.

The principle of pneumatic control is not new, but its advantages for actuating mechanisms on automatic machinery are now being recognised on an ever increasing scale. Air gauging whereby a thin air cushion prevents actual contact between the measuring head and the object, not only enables dimensions of delicate materials to be gauged but back pressure on the air jet can be used for ultra sensitive multi-head measurements on large scale production of engineering parts. More recent developments have been air-springing of vehicles and air bearings, the latter being of particular interest owing to the small losses due to friction compared to conventional lubricants. The most startling advances in the use of air are now seen in the development of the Hovercraft and the Air Car by Saunders-Roe Ltd. and the Ford Motor Co. in the U.S.A. respectively. These inventions may well create a revolution in transport vehicle design in the years ahead and they stimulate the imagination to visualise an amphibious motor car which does not require smooth roads and which could be made collision-proof by an air barrier. One of the earliest engineering uses for air—in the pneumatic tyre—is still under development, for it is reported that when bound up in the form of foam and pumped into a normal tyre it gives approximately the same characteristics as pure air but the tyre cannot be punctured even by bullets.

Because of the recent dispute in the printing industry, it has been necessary to combine the August and September numbers of ENGINEERING MATERIALS AND DESIGN *into this single edition. We regret the necessity for this and for certain other changes introduced to simplify production.*

Although—because of the dispute—some copies of the July issue did not contain a prepaid Reader Service card, more details of products mentioned in it may be obtained by using the card included in this present edition.

Arrangements are being made to extend readers' subscriptions to compensate for the effective loss of an issue.

POROUS FIBRE METAL

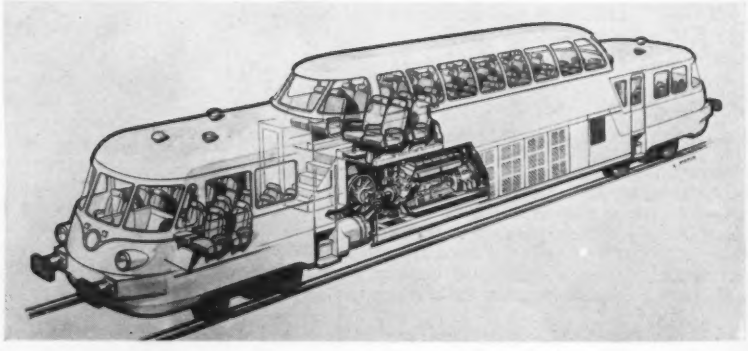
Demonstrating the remarkable porosity of this rigid sheet of fibre metal is Dr. Robert H. Read, a scientist at the Armour Research Foundation of Illinois Institute of Technology; he is a member of the team that was responsible for the development of the material. (Photo: Frontier Magazine.)

LIFTS AND LAUNCHES

Eliminating the need for massive gantry towers, this erector-launcher boom was built by Convair for use with the Atlas I.C.B.M. The missile may be stored horizontally and quickly raised when needed. After reaching the upright position, the nose clamp opens and the boom swings back out of the way.

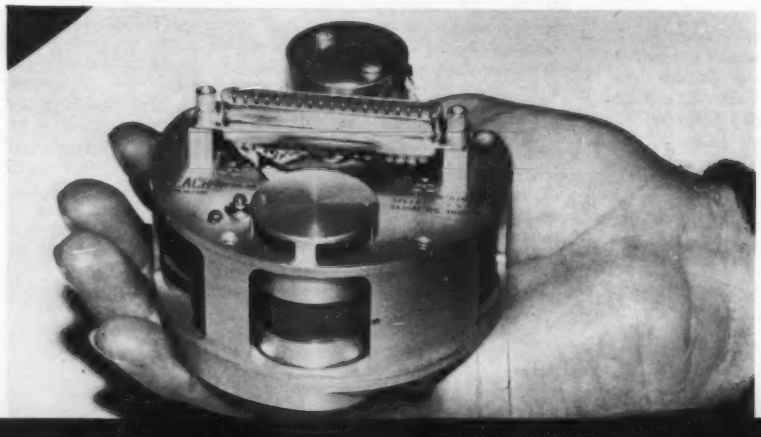
PICTURE NEWS

IN THE WORLD OF MATERIALS & DESIGN



GLASS FIBRE TRAIN

This Renault passenger locomotive marks the first extensive use of plastics in France for railway equipment. Major body components are of glass-reinforced polyester, and other plastics are used for internal steps, fuel reservoirs and air conditioning ducts. Double windows contain a plastics film with an electrical resistance element, to prevent misting and freezing.



SMALLEST TAPE RECORDER

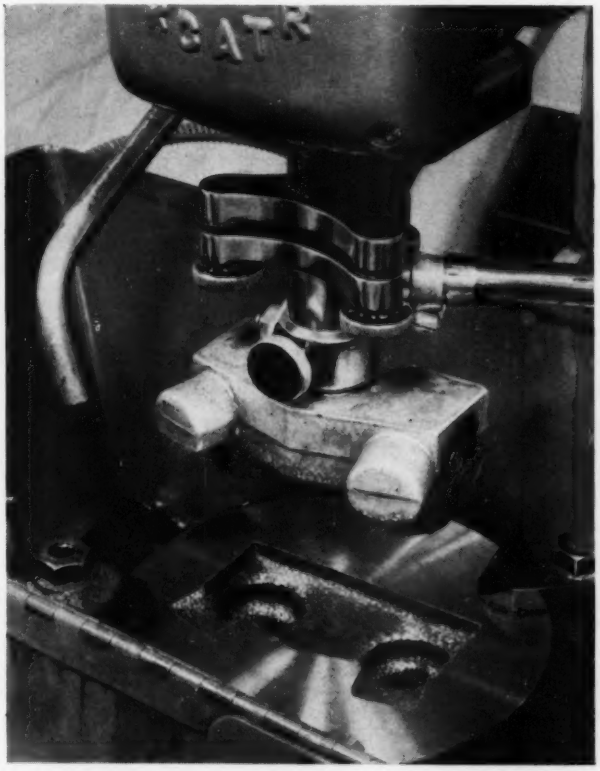
Claimed to be the smallest yet developed, this tape recorder is 3½ in. in diameter and weighs 24 oz. Made in the U.S.A. by the Leach Corporation, it is intended mainly for in-flight tests, blast and explosion studies, oil well logging and various other tests.

OIL LAMP POWER SUPPLY

This thermoelectric generator converts the heat of an ordinary oil lamp into electrical energy. Developed at the Leningrad Institute of Semiconductors, it has a junction-type thermoelectric two-watt generator mounted round the chimney with a device that converts thermoenergy to electric power. It was shown at the International Transistor Exhibition by Wayne Kerr.

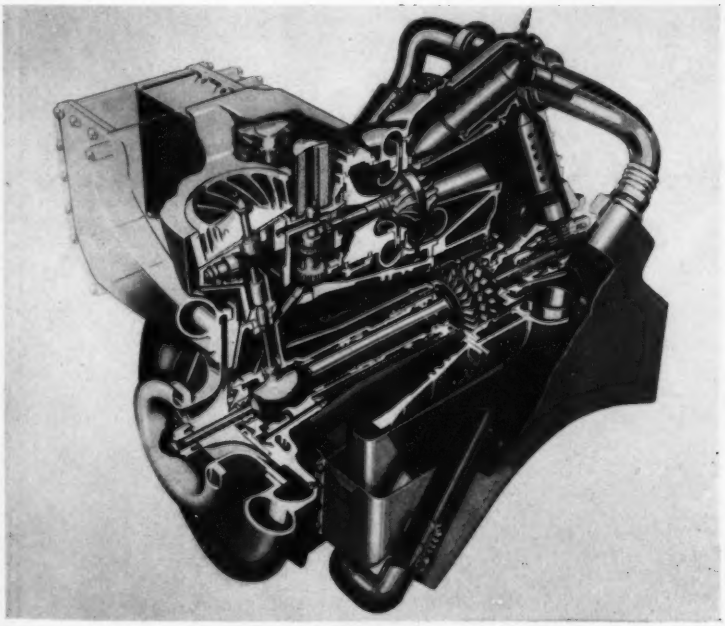
SPARK MACHINING

New development in spark machining is the Sparcatron R.I.G. equipment intended mainly as a roughing medium, with a rate of stock removal very much faster than a standard machine. This picture shows a close-up of the electrode used and a die which has been spark machined on this equipment.



LIGHTWEIGHT GAS TURBINE

This is the "704," a supercharged gas turbine engine of 300 h.p. built by Ford-U.S. It weighs 650 lb. installed—a quarter of that of a comparable diesel engine. It has two stages of air compression, one supercharging, enabling it to deliver more horsepower from a smaller size.



EASY-TO-READ METER

A new house service meter designed by English Electric Co. for easy reading by the householder is now being installed in rural areas. Number wheels of the register are mounted on stainless steel spindles and are made of highly polished black acrylic resin to resist temperature and humidity variations.

Ultra-fine Powdered Aluminium

THE NATIONAL RESEARCH CORPORATION in the U.S.A. has developed a new process for the production of ultra-fine metal powders, the particle size of which ranges from 200 to 600 angstroms. The particles are spherical and the size may to some extent be controlled, future developments suggesting that it will be possible to reduce the size to as low as 50 angstroms. As spherical particle size decreases, an increasingly large percentage of atoms is at the surface and they therefore have free energy due to unsatisfied bonds.

As a result of the increase in surface energy, there will be an increase in heat of combustion, increase in rate of reaction, increase in absorption and a tendency to act as a thickener when added to liquids. These property changes offer new opportunities in propellant formulation, catalysis, organometallic reactions, powder metallurgy and electronic applications. Some of the materials which may be reduced to this small particle size are aluminium, iron, nickel, magnesium, lead, zinc, copper, silver and gold. As yet the process cannot be applied to refractory metals such as titanium, zirconium and tungsten. Using these ultra fine metal powders it appears likely that dispersion hardening may be effected by suitable orientation.

Weight Engineering

THE AIRCRAFT INDUSTRY must necessarily place great importance on weight as a factor in design and most of the larger companies employ weight engineers who specialise in the calculation of weights and advise on materials. A Society of Weight Engineers has recently been formed to promote weight engineering techniques in industry and to maintain this specialised approach as an established career. While the founder members are mainly employed in the aircraft industry it is recognised that the field of application of light-weight design is very much wider than that and already includes the motor industry, shipbuilding and the manufacture of portable tools and equipment. Weight engineers in fact already exist outside the aircraft industry although they are not often known by that name. One of the useful objects of the new organisation is to promote interchange of ideas and experiences between those engaged in the aircraft industry and those in a similar field of activity elsewhere. Information on materials, methods of estimating weight and the compilation of a Weight Data Handbook are some of the subjects to be discussed in the near future.

Research in Chromium

IN THE SEARCH for materials which offer high strength, resistance to creep and fatigue at elevated temperature with a minimum of corrosion, chromium is receiving a great deal of attention in many parts of the world.

Pure chromium in its annealed form has a tensile strength of approximately 41,000 p.s.i. and 14 per cent elongation at 330 deg. C., the latter property indicating its main disadvantage—extreme brittleness. At 1070 deg. C. it becomes more ductile (104 per cent elongation) with an ultimate tensile strength of 9,000 p.s.i. By virtue of its highly reactive nature, chromium is likely to remain expensive both as a wrought metal or as a finished product.

To increase its ductility at room temperatures and therefore the case of manufacture, considerable effort is being expended in a search for suitable alloying agents by, among others, the Fulmer Research Laboratories, which is equipped for fundamental research test and analysis on ferrous and non-ferrous materials and products.

Microcrystalline Glass

DEVELOPMENT OF A NEW MATERIAL named Sital has been reported from the State Scientific Research Glass Institute in Russia. Although derived from glass it is not a true glass because its structure is microcrystalline and the dimensions of the particles composing it are of the order of one micron. Sital is stated to be four times stronger than glass, to be harder than a high-carbon steel and lighter than aluminium. Electrically it is said to be superior to ceramics and its resistance to high temperatures very good, as it does not soften below 1400 deg. C. Being made from glass of a special composition by a special heat treatment the material is inherently corrosion resistant and its unique combination of properties suggests many uses in chemical and general engineering.

Tilting Trucks

MAKING USE of aluminium's light weight, several commercial vehicle manufacturers are now building truck bodies in which the entire goods compartment can be adjusted or even tilted to the level of any loading platform. The Rootes Group, for example, now produces a 5-ton van known as the Cargo-Lift. For loading on to aircraft, the body can be lifted to a height of 13 ft. to provide ready access to the loading hatches of most aircraft by means of a scissor-action twin-ram hydraulic hoist. Width and height may be varied.

In the U.S.A., the Thompson Trailer Corporation produces a 5-ton truck known as the Leveloder, the body of which may be hydraulically tilted forward or backward, tipped to either side, raised or lowered to ground level. Principal users of this typé of truck so far have been airlines and carriers of perishable foods; loading and unloading time is said to be reduced by up to 75 per cent.

Metal Fibres

A NEW TECHNOLOGY is growing up in the field of fibre metallurgy which is centred around processes in which metal fibres are felted as in paper-making and then sintered as in powder metallurgy. The product is a continuous metal network in which the pores are continuous, leaving no blind pores which are characteristic of metal powder products. A further advantage claimed is that metal fibres can be prepared at low densities and high porosities which are virtually impossible for powders, and this makes them attractive for filters. Other applications suggested include reinforcement of plastics, ceramics and even other metals. Steel fibres used for reinforcing magnesium do not give superior strength but greatly improved elastic modulus and impact strength.

IN NEXT MONTH'S ISSUE . . .

Principal features planned for the October issue of ENGINEERING MATERIALS AND DESIGN include:

Flow Formed and Power Spun Components
Current practice and design possibilities here and abroad.

High Alloys of Chromium, Cobalt, Columbium, Molybdenum and Vanadium
Their development and use in high operating temperatures.

Rubber and Ebonite for Linings and Coatings
Their application for corrosion and abrasion protection.

Selection of Bearing Materials
Using friction materials with or without lubrication.

FOR MORE INFORMATION

U.K. Atomic Energy Authority, 11 Charles II Street, London, S.W.1.

International Plastics Exhibition, Dorset House, Stamford Street, London, S.E.1.

Society of Weight Engineers, Holborn House, 113 High Holborn, London, W.C.1.

Fulmer Research Institute Ltd., Holley Hill, Stoke Poges, Bucks.

Thompson Trailer Corporation, Pikesville, Maryland, U.S.A.

Saunders-Roe Ltd., Osborne, East Cowes, Isle of Wight.

Ford Motor Co., P.O. Box 207, Dearborn, Mich., U.S.A.

Engineering Materials and Design

WHEN ARE PATENTS WORTHWHILE?

MORE than 42,000 applications for patents were made last year, nearly 2,000 more than in 1957, and a little over 30,000 complete specifications were filed. These facts were disclosed in the annual report of the Comptroller-General of Patents, Designs and Trade Marks, recently published. It states that the Patent Office received nearly £1¼ million in fees in 1958, although the total cost of running our present patent system must be several times this figure when account is made of fees to agents, time spent by firms or individuals in drawing up draft specifications and sundry expenses connected with them. In planning economies an obvious target is the Patents Department, where this exists, or the Design and Development Section where many patents originate and where much time may be spent on them.

Many engineering firms run elaborate patent departments which produce a continuous flow of patent applications, but it is questionable whether sufficient distinction is drawn between inventions of an advanced and highly technical nature which justify patent cover and those relating to trifling improvements in the design of ordinary products.

When asked why they spend time and money on patent coverage, many firms have replied in general terms referring to "protection against competition", "prevention of competitors making use of our research and development work", and "establishment of claim to being first in the field". There are, however, a number of other advantages in running a patent system and, although they are more difficult to assess in terms of money, it is instructive to see how other countries are encouraging the activities of their inventors. In the U.S.S.R. high rewards are being planned for inventors, and a revision of Soviet laws governing the recognition of innovations and the scale of grants which may be made to persons contributing to technical and scientific advances is now being drafted in Moscow. All useful inventions, of course, remain the property of the State, but the new laws aim to increase the money grants and give personal recognition to the inventor. Inventors will also be granted additional leave and passes to health resorts and the law will provide for conferring a gold medal and the title "Merited Inventor of the U.S.S.R." It appears that the Soviet Union is doing all this as an encouragement to creative men.

In the U.S.A. a recent investigation was made under the sponsorship of *Industrial Relations News*, who asked 105 experts "in the area of creativity" to give their views on special awards for invention in industry. From these results it was concluded that the desire to solve problems, the satisfaction of accomplishment and the desire to win prestige were more important than financial reward, although the experts were equally divided as to whether special bonuses should be given to inventors.

In the U.K. the Government has recently proposed to extend for a further ten years the power of the Board of Trade to advance money to the National Research Development Corporation and to increase the limit of advance from £5 million to £10 million. The N.R.D.C. is expected not only to help the exploitation of ideas from research organisations, but also to develop any private inventions which seem worth while. Here, again, is evidence of encouragement to creative thinking. Many engineering companies in this country already give cash bonuses to their staff when they have produced ideas for successful patents, but this form of encouragement is by no means universal for there are a number of organisations who take no active interest in such matters, relying on secrecy to cover up their technical advances, if any.

The British patent system has much to commend it, for by leaving the enforcement of patent rights to civil actions a natural process of selection is brought about because the owners of worthless patents would obviously not spend money in trying to protect them. In this connection it is interesting to note that fees in respect of the fifth year of a patent are only paid on about half of the original number of completed specifications, the figures dropping rapidly with time to one in six for the tenth year and one in fifteen for the sixteenth year. This suggests that a large proportion of the patents taken out do not pay their way. It is undeniable that many patents are used successfully for protection and as a means of negotiation for selling ideas. The large number of engineering firms who take an active part in patenting their inventions is proof that patents are a necessary part of our industrial life, but if economies are thought to be necessary there may be some scope in carrying out a more thorough search to locate any patented prior art. Such a search is likely to be less expensive than filing a patent application and may show that many ideas are not worth covering.

Creative thinking must be actively encouraged in this country if we are to keep abreast of the technical advances in the U.S.A. and Russia. This is more important for Britain than for many other countries, because we depend so much on exports for our existence. Our limited home market makes it difficult to compete with the U.S.A., for example, in mass-produced articles, but we can and should develop products with a high content of technical "know-how". Even the ideas themselves can sometimes be exported as patents.

This 2-ft-high flexible pipe flange is the result of dip-moulding a steel section in p.v.c. and subsequently separating the two materials.

PLASTICS COATINGS FOR CORROSION PROTECTION

Where resilience and good corrosion resistance are essential, plastics coatings—applied by either dipping or spraying—have been found to offer definite advantages. This article indicates which coatings will be found most suitable in specific conditions

THE development of plastics for engineering applications is often limited by adverse mechanical properties such as tensile strength and creep. The cheaper metals such as mild steel, while having satisfactory mechanical properties, do not have sufficient resistance to corrosion to be used for many applications without a surface finish of electro-plating or painting. At the same time, the relatively high cost of plastics frequently does not permit their being used for replacement of steels. Interesting new developments are taking place in the production of plastics-coated steel which has high strength and, at the same time, is resistant to corrosion and chipping.

At present, such materials are available mainly in sheet, rod or tube, but for many engineering purposes parts are required to be made in complicated and intricate shapes. In such cases, the application of a plastics coating on a finished casting or fabricated product combines the best properties of metal and plastics in the most economical manner. Many plastics can be applied simply and cheaply by dipping or spraying and the resultant coatings have properties which are, in many cases, greatly superior to those obtainable from paints. If required, special pretreatment processes may be carried out to ensure a first-class adhesion of the plastics to metal, and even polyethylene and p.v.c. can be applied to steel so firmly that they cannot be peeled off, attempts to do so resulting in the plastics breaking first.

Polyvinyl Chloride

Polyvinyl chloride is probably the most versatile of all plastics coating materials, its two outstanding characteristics being resilience and corrosion resistance.

It is applied by dipping or spraying, generally by the former, as this shows great economies from the rapidity of output and the high build-up of thickness of coating: anything up to $\frac{1}{4}$ in. is obtainable by one dipping on suitable substrate metals having sufficient thermal capacity. The chemical and temperature resistance is dependent to some extent upon the choice of plasticiser. Because it is a liquid process, it is not always possible to obtain attractive, uniform and drip-free coatings without excessive processing time, which may override the initial advantages of a comparatively cheap raw material. Thus, for decorative finishes other coatings such as polyethylene and nylon are generally cheaper for these applications, through being easier to apply.

A p.v.c. coating does not adhere to a steel surface without the use of a primer or adhesive interlayer. However, by first coating the steel with a suitable adhesive (based on nitrile rubber and phenolic resin) then applying p.v.c. by spraying or dipping and consequently stoving this coating, excellent adhesion can be obtained. Generally it is not necessary with p.v.c. to raise the substrate metal above 180 deg. C., unless the metal is of extremely thin gauge.

Typical applications have been:

1. Lining pipes and valves to give abrasion- and chemical-resistant coatings.
2. Coating heavy-duty fume-extraction equipment, where the best of both worlds is required, i.e., the combination of the strength of metal and the corrosion resistance of plastics coating.
3. Insulation coating of anodes used for corrosion protection systems and subsequently buried in the earth or mounted on the hulls of ships, etc.
4. Very thick cushion coatings on stillages and jigs, to give protection to chromium-plated parts and to engine gears, etc.
5. The proofing of all-metal tanks to hold corrosive liquids. Coatings can be tested for porosity by high-voltage spark.

Polyethylene

This is the most easily applied of all coating plastics, being outstandingly corrosion resistant and having an attractive, smooth appearance, ease of application and comparatively low raw material cost. Two grades are available, high-density and low density. H.D. polyethylene has a higher melting point, is tougher, but does not give quite such a decorative coating; it has better adhesion to substrate metals. L.D. polyethylene is simpler to apply and gives a more attractive coating, but has a lower melting point and is not quite so tough. Both grades are powders applied by dipping or spraying, generally by dipping, as this enables high rates of output and good control. Thickness of deposit is dependent on the thermal capacity of the substrate metal, but generally speaking can be varied from 10 thou. to $\frac{1}{16}$ in. To obtain this, however, the metal must

be sometimes pre-heated to temperatures as high at 300 deg. C. Thus, soft soldered fabrications cannot be coated. There are some dangers in using polyethylene as a coating on sheet metal, due to environmental stress cracking set up by the difference in thermal coefficient of expansion between the coating and the substrate metal. Such dangers can be overcome on suitably prepared surfaces, using special keying techniques to cut down stress.

Typical applications of polyethylene coating include all normal forms of wirework, including refrigerator shelves, where it gives a smooth, easily-cleaned finish without tears or drips. Another common use for polyethylene coatings is for the insulation and corrosion protection of electrical fittings, including fluorescent holders, conduit and conduit junction boxes, where it combines the corrosion protection of polyethylene with the earthing and fireproof qualities of metal.

Coating of clips, springs and brackets, where a smooth, uniform coating is obtainable which by the powder process prevents infilling of undercuts, is also achieved with this material.

Nylon

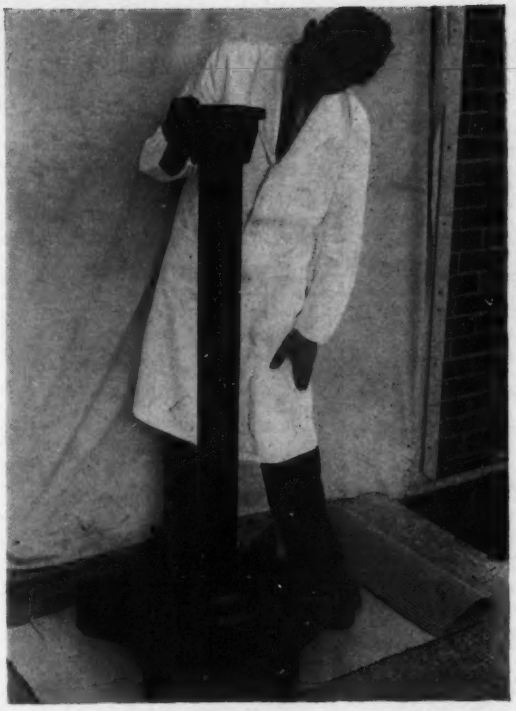
Nylon coatings give outstanding adhesion and attractive tough surfaces. They may be applied as powders either by spraying or dipping followed by sintering, but generally they cannot be satisfactorily applied to articles with a melting point below 180 deg. C. The coatings are non-toxic and can be sterilised, which makes them ideally useful for the lining of vats and equipment for the foodstuffs industry and for the lining of equipment carrying demineralised water and where a non-contaminatory surface is required. Other applications are the coating of instrument cases to give attractive and, at the same time, insulating surfaces. Another example is the coating of textile thread guides where the nylon gives a smooth, uniform covering and saves expensive dressing operations on castings as well as the high cost of chromium plating which it replaces. It can be applied in thicknesses of between 10-40 thou.

Neoprene

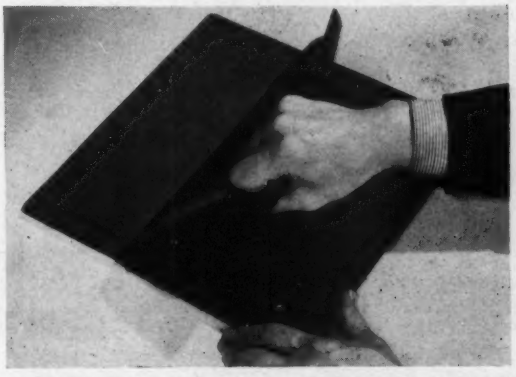
Neoprene, although not a true thermoplastics, is closely allied and, although it is generally considered to be inferior in properties, it has certain outstanding advantages. Primarily it can be applied cold and no subsequent curing or heating cycle is necessary. It is thus admirable for on-site work and for articles that are generally too large to stove. Its chief characteristic is high abrasion resistance, which makes it most suitable for lining salt-water pump impellers and pipework generally. Its corrosion resistance is only reasonable but it is particularly resistant to oils. It is most suitable for cases of mild atmospheric corrosion, rather than cases of submersion corrosion. The coating can be either brushed, dipped or sprayed, up to ¼ in. thick, and a catalytic cure can be accelerated with mild heat if desired.

P.T.F.E.

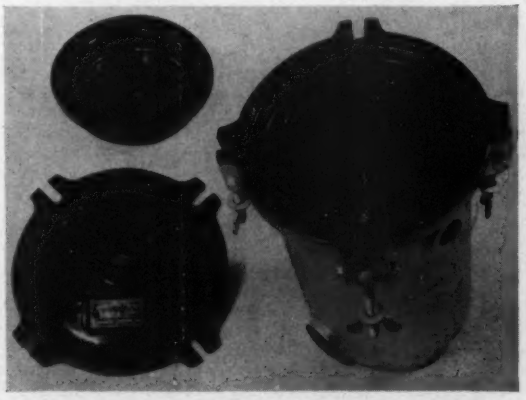
Polytetrafluoroethylene is one of the most remarkable synthetic materials ever produced. The extraordinary properties of this material resolve many outstanding design problems. It remains virtually unaffected from −80 deg. C. to +250 deg. C. It has an extremely low coefficient of friction, is non-wetting and resistant to practically all known chemicals (except fluorine and chlorine trifluoride at high temperatures) and molten alkaline metals. It is non-corrosive and has a volume resistivity as low as 10^{17} ohms/cm. Sprayed coatings can be applied in thicknesses from 0·0005-0·006 in. at the rate of approximately 0·0005 in. per coat. Apart from copper and some brass alloys, coatings can be applied to any metals or glass



A p.v.c. coating on this chemical stirring paddle gives good corrosion resistance and thus obviates the use of stainless steel.



Continual flexing and pulling will not break the bond between this steel plate and its p.v.c. coating.



A nylon-coated filter unit for de-mineralised water. Nylon coatings are non-toxic and can be sterilised, and have high resistance to solvents and oils.

TABLE 1. Chemical characteristics of plastics coatings

	P.V.C.	Nylon	Polyethylene		P.T.F.E.	P.C.T.F.E.	Neoprene
			L.D.	H.D.			
Safe working temp. range, °C.	−40* +105*	−60 +140	−70 +95	−80 +120	−80 +250	−70 +200	−50 +110
Vol. resistivity at 20°C. ohm./cm.	4×10^{9}	10^{13}	3×10^{17}	10^{16}	10^{17}	10^{16}	10^{12} (variable)
Possible thickness of deposit	0·015–0·4	0·008–0·075	0·008–0·2	0·008–0·006	0·0005–0·006	0·005–0·015	0·005–0·025
Gen. chemical resistance	Good*	Fair	Very good	Very good	Complete	Exceptional	Fair
Oil resistance	Good	Excellent	Fair	Fair	Complete	Complete	Excellent
Abrasion resistance	Very good	Excellent	Fair	Good	Poor	Good	Very Good
Adhesion on suitable surfaces	Very good	Very good	Satisfactory	Good	Good	Good	Good
Inflammability	Self extinguishing	Will burn	Will burn	Will burn	Non-inflammable	Non-inflammable	Will burn
Shore hardness	78–85	95	85	90	75	97	75–80
Toxicity	Very slight	Non-toxic	Non-toxic	Non-toxic	Non-toxic	Non-toxic	Very slight
Colour range	Full	Limited	Full	Limited	Natural black	Clear	Limited
Max. temp. to which parts will be pre-heated, °C.	150	180	160	180	300	250	80
Application	Dip/spray	Dip/spray	Dip/spray	Dip/spray	Spray	Spray	Dip/spray

* Depends on amount and type of plasticiser

capable of withstanding the stoving temperatures of up to 350 deg. C. Unlike p.c.t.f.e., p.t.f.e. gives micro-porous coatings and thus may not be suitable for many corrosion-resistant purposes. Successful applications have been:

1. Lubricant, non-icing coatings on aircraft equipment.
2. Lubricant coatings for tapered valves and cocks.

This artesian well bridge perforated pipework was coated with neoprene approx. 0·030 in. thick to prevent corrosion and electrolytic deposit of scale and mineral matter.

This p.t.f.e. coating on a tyre mould permits the use of sticky rubbers and cuts cycling time because of rapid release.

3. Non-stick coatings to printing feed equipment.
4. Quick-release coatings for sticky foodstuffs, dough, chemicals, etc.
5. Epoxide and rubber mould release coatings.
6. Anti-flash coatings for the faces of porcelain insulators.

Surfaces should preferably be prepared by very lightly vapour- or shot-blasting, and should be in a degreased, non-rusted condition.

P.C.T.F.E.

Polymonochlorotrifluoroethylene, though not possessing quite the same outstanding chemical- and heat-resistant properties as p.t.f.e. in solid form, is far more useful as a sprayed corrosion-resistant coating because a completely non-porous deposit can be achieved at 0·004-0·012 in., dependent upon the substrate. This is built up from layers of approximately 0·001 in. at a time.

P.C.T.F.E. is suitable for use up to and including temperatures of 200 deg. C., and can be applied to all metals capable of withstanding the stoving temperatures of approximately 250 deg. C. Brass and copper, however, are normally better plated in nickel if good adhesion is required. Dispersion coatings of p.c.t.f.e. have generally better mechanical and electrical properties than p.t.f.e., because of their non-porous, tougher nature. Preparation of the substrate metal is most important. All corners must be well radiused, welds ground down, and any porosity in the castings filled, as these can cause blow holes in the coating, due to entrapped air. Other surfaces should be lightly shot blasted.

Typical successful applications have been:

1. Corrosion proofing of magnesium castings for high-temperature aircraft work.
2. Corrosion proofing of concentrated acid pipelines.
3. Insulation of radar wave guide equipment.
4. Corrosion proofing of chemical vats, paddles, etc., enabling these to be made from ordinary mild steel.

Coatings can be fully checked for non-porosity by an electrical breakdown test.

Both p.t.f.e. and p.c.t.f.e. are expensive, which tends to limit their application as coatings to special problems.

We wish to acknowledge with thanks the co-operation given with this article by Mr. Nigel Vinson, managing director of Durable Plastics Ltd.

SIGNIFICANCE OF MECHANICAL PROPERTIES OF METALS IN DESIGN

Mechanical properties provide more information than mere strength data for design purposes. In this article, some simple mechanical test results are discussed in relation to the subsequent performance of the material concerned

by D. BIRCHON, B.Sc., A.I.M., A.I.Mar.E.*

THE optimum design of any structure or component can only be achieved by a judicious blend of experience, design philosophy, economics, materials selection and fabrication processes. Of these, materials selection is often dismissed rather lightly because of its complexity. Apart from the fact that the materials selected affect almost every aspect of subsequent design and construction, the basis of their selection should embrace every known mechanical and environmental condition to which they will later be subjected.

The physical properties of engineering materials are necessarily specified in terms of more or less standardised mechanical tests, and it is necessary to appreciate both the value and the limitations of the results of such tests. The importance of this interpretation may be judged from the fact that, although the tensile strength is the most commonly quoted physical property, most service failures in ductile engineering materials arise from fatigue, selective corrosion or brittle fracture phenomena. Each of these fracture processes is associated with a minimum of plastic deformation and the tensile strength of the material is involved only indirectly. It is therefore appropriate to consider some of the conventional mechanical testing procedures, not only in terms of the direct quantitative information which they provide, but also in terms of the qualitative inferences which may be drawn from their results.

Tensile Strength

When a ductile material is pulled in tension, the relationship between the applied load and the resulting strain will appear as shown in Fig. 3. Up to a certain load, the relationship is essentially linear, with a slope corresponding to the modulus of elasticity of the material. The limit of proportionality is closely related to the elastic limit, i.e., the point beyond which full elastic recovery will not follow removal of the load, but these two points are rather nebulous and dependent upon both the sensitivity of the extensometer employed and the rate of loading and unloading. For design purposes it is usually sufficient to know the load which will result in some small, yet readily measurable amount of permanent strain remaining in the unloaded material.

In structural low-carbon steels the well-known yield phenomena, caused by running dislocations temporarily outstripping their attendant "pegging" atmospheres of solute atoms, provide a convenient indication of the onset of plastic deformation. In materials which do not exhibit a yield as shown in Fig. 3 (b), the proof stress, P, which will produce a permanent set, X (usually 0·1-0·3 per cent), is used instead.

Once the yield or proof stress has been exceeded in a tensile test of a ductile material, the specimen exhibits more or less uniform plastic extension along its length. This results in a reduction in cross-sectional area. The nominal stress is calculated as the ratio of the applied load and the original cross-sectional area. The elastic cross-sectional change is so small up to the onset of plastic deformation that negligible error is introduced. But beyond this point the error becomes considerable, as shown in Fig.

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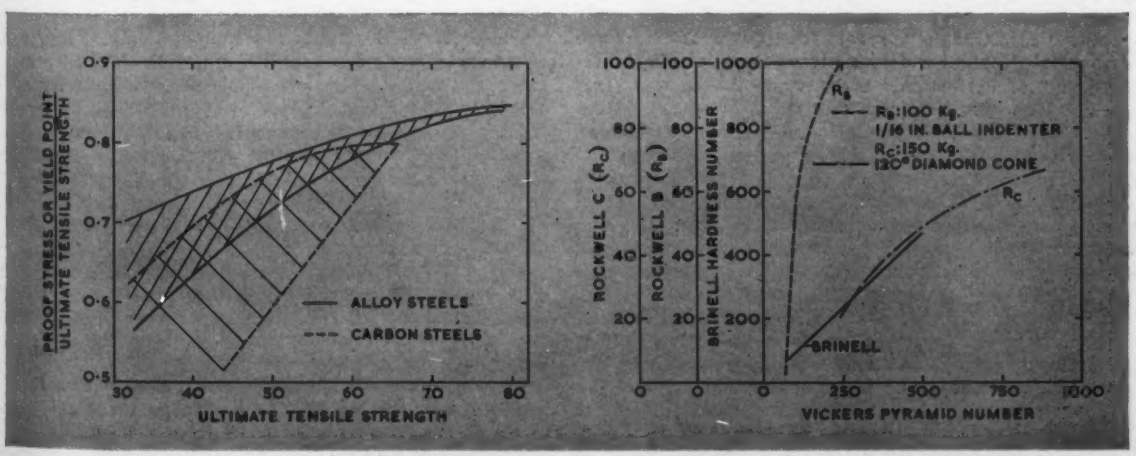


Fig. 1. Typical limiting values of the proof stress/U.T.S. ratio for plain and alloy steels in various conditions of heat treatment.

Fig. 2. Approximate equivalent values for Vickers, Brinell and Rockwell B and C scales of hardness.

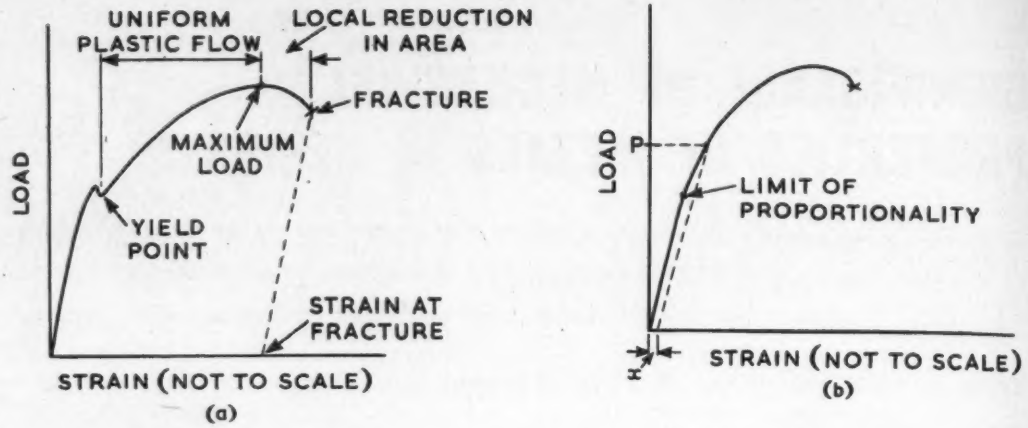


Fig. 3. Typical load extension curves for ductile materials. (a) is typical of annealed or normalised steels having a yield point. (b) is representative of steels hardened by cold work or heat treatment, and of many non-ferrous materials.

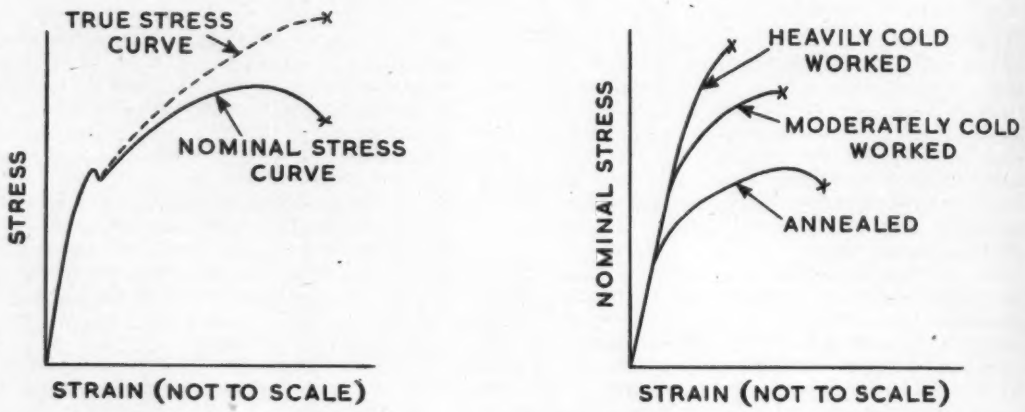


Fig. 4. Comparison of conventional stress-strain diagram with true stress-strain diagram

Fig. 5 (far right). Effect of cold work upon the tensile properties of an annealed low-carbon steel.

4. This distortion of the truth becomes particularly obvious when the applied load reaches a maximum and then begins to fall. This part of the diagram corresponds to the localised reduction in area of the material at the zone in which fracture will eventually occur. If allowance is made for this rapid fall in cross-sectional area, the true stress-strain curve continues to rise as in Fig. 4. The ultimate tensile strength, which is the ratio of the maximum load to the original cross-sectional area, is therefore an artificial figure. Its continued use is due to its value for comparison purposes, the convenience with which it can be obtained and the vast amount of experience which has been accumulated in its use.

Consideration of the true stress-strain diagram of a ductile material emphasises its ability to absorb large amounts of plastic deformation. Considerable work-hardening of the material accompanies this process. This feature is frequently exploited to render engineering designs intrinsically "fail-safe", since an unexpected overload in one section will result in yielding and an associated redistribution of peak stresses. This ability is particularly important in conditions of stress-concentration, as we shall see later in the section dealing with fatigue.

In an attempt to provide a separate index of the amount of plastic deformation absorbed by a fractured tensile test piece (and therefore the work-hardening capacity of the material), it is usual to quote the elongation or reduction in area of the gauge length of the specimen. Since much of the elongation is associated with the disproportionate deformation adjacent to the fracture, it is obvious that the gauge length over which the elongation is determined has a marked effect upon the final value obtained. For comparison purposes between test specimens of differing diameters there is much to be said for standardising the gauge length at $4\sqrt{\text{cross-sectional area}}$. The reduction in area at the fracture is independent of the gauge length, and is a very sensitive index of the ability of the material to absorb plastic deformation. But an examination of the shape of the fracture can provide other information. If the material has distinctly directional properties, the shape of the section at the point of fracture will be roughly elliptical, and the ratio of the major and minor axes will provide an indication of the relative work-hardening propensities in different directions.

The difficulty entailed in designing structures to carry stresses in the plastic region, combined with the safety inherent in designing on yield or proof stresses, is such that the demand has always been for improved proof stress. These higher proof stresses can, however, only be obtained at the expense of other properties. In general, as the proof stress and U.T.S. of materials increase, the ductility and ability to work-harden decrease. This is shown in Fig. 5 for a plain carbon steel strengthened by cold work. The suppression of the yield point (which is transitory unless non-ageing steels are employed) is a valuable preliminary to deep drawing operations, since localised yielding may result in deformation bands which can only be polished out at considerable expense.

Materials which may be strengthened by heat treatment display a similar series of stress-strain relationships as the U.T.S. is increased. In both cases the elongation and reduction in area at fracture decrease with increasing strength, indicating a reduction in work-hardening capacity. A very useful index of the work-hardening capacity of a material is afforded by the ratio of the yield point or proof stress to the U.T.S. The limits obtained in a plot of this ratio against tensile strength for a range of plain carbon and heat-treated low-alloy steels are shown in Fig. 1. It will

be noticed that rather lower ratios are obtainable with plain carbon steels than with alloy steels. This ratio, or its reciprocal, has often been proposed as a measure of the inherent work-hardening capacity or deformability of the material. It is very closely associated with the ability of the material to withstand stress concentrations by local yielding and the subsequent redistribution of stress, and also with its ability to withstand high rates of loading.

Unfortunately, it is not a quantitatively definable characteristic, but, in general, wherever this index exceeds approximately 0·75, attention must be given to surface finish, corner and fillet radii and sometimes even loading rates.

Hardness

The hardness of a metal has been defined in a number of ways and an even larger number of tests have been proposed for its determination. The methods most widely adopted today are the Vickers, Brinell and Rockwell, each of which basically measures the resistance of the material to indentation. There is no precise relationship between the results of these tests, but typical conversion values are shown in Fig. 2. Vickers and Brinell values are closely similar up to 300, but beyond this hardness the intrinsic value of the Brinell test rapidly declines.

The most discriminating and universally applicable test is generally agreed to be the Vickers, but for most ordinary engineering purposes the Brinell test provides results less open to abuse and misinterpretation. This is due to the comparatively large indenter and load used in the Brinell test. Under the more or less standard load of 30 kg. used in the Vickers test, the diamond indenter (a pyramid of apical angle 136 deg.) penetrates only $2{\cdot}3 \times 10^{-3}$ in. into the surface of a steel of 50 t.s.i. tensile strength. Slight surface cold work or decarburisation resulting from heat treatment can thus easily invalidate the results obtained.

The hardness test is deceptive in its apparent simplicity, and this often results in insufficient care being taken during testing. Portable hardness testers are particularly liable to misuse, as they are often expected to work upon large components having relatively poor surface finishes. In the author's experience, grossly inaccurate hardness results are so often quoted that care should always be exercised in acceptance.

Hardness can give a measure of the tensile strength, but it is not necessarily a very good index of machinability or fabricability. The Vickers hardness number multiplied by 0·22 yields a very good approximation of the tensile strength of carbon and alloy steels, but this relationship does not hold for austenitic or severely cold-worked steels. No similar relationship applies to non-ferrous materials, though the hardness still represents a sensitive index of other characteristics. For a given type of material an increase in hardness usually implies an increase in proof stress or yield and therefore a decrease in ductility. In materials hardened by cold working, the increase in proof stress is accompanied by an increase in the residual stress system within the material and an accompanying increase in hardness. But the hardness cannot be interpreted as an indication of susceptibility to self-induced stress corrosion cracking.

Izod and Charpy Tests

These tests, in which the energy required to fracture a notched specimen is determined, are a supreme example of an apparently simple test which provides information about most complex behaviour. Neither test measures the

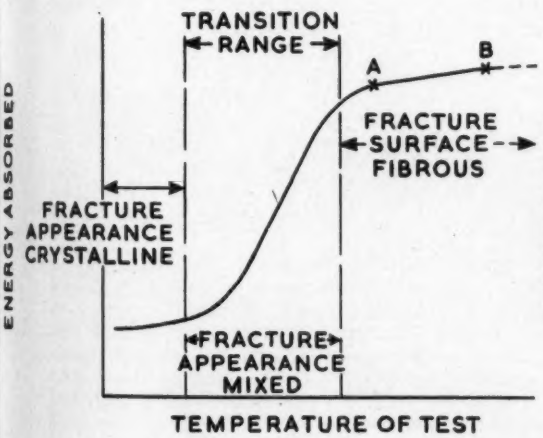


Fig. 6 (far left). Typical transition curve.

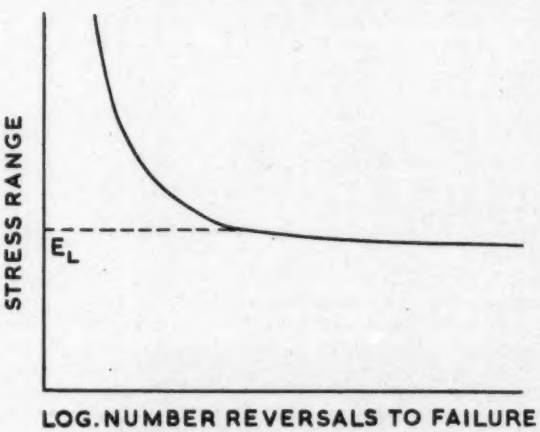
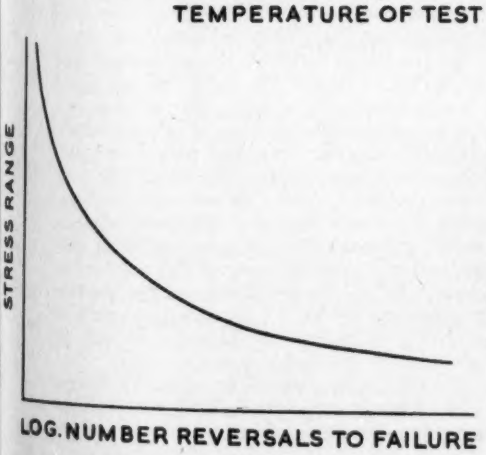


Fig. 7. An S-N curve for a material with a fatigue limit E_L.



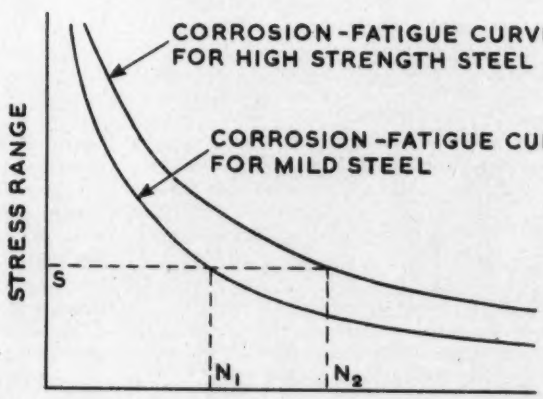


Fig. 8 (far left). An S-N curve for a material with no definite fatigue limit.

Fig. 9. Under corrosion fatigue conditions a material of greater nominal fatigue strength will merely have a longer life, as from N_1 to N_2.

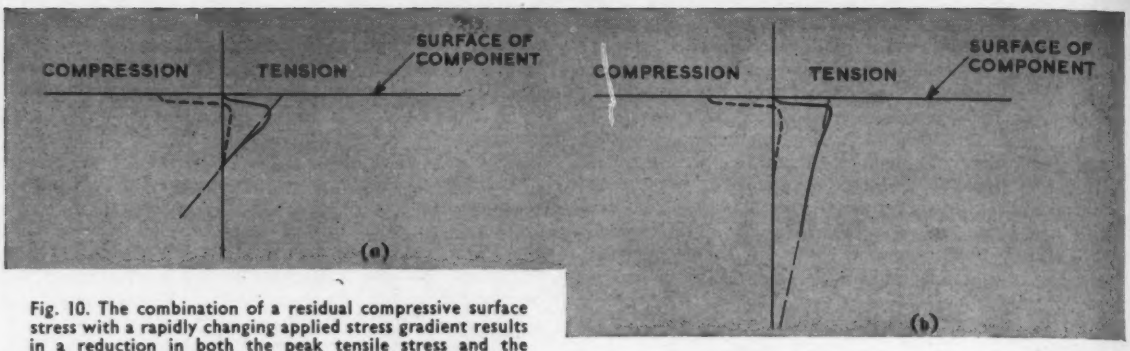


Fig. 10. The combination of a residual compressive surface stress with a rapidly changing applied stress gradient results in a reduction in both the peak tensile stress and the surface tensile stress, as shown in (a). In (b) is illustrated the combination of a shallow surface compressive stress with a slowly-changing applied stress gradient. In this case the surface stress is reduced, but the peak tensile stress may even be slightly increased. Under these circumstances, a fatigue crack may initiate beneath the surface.

resistance of the material to impact, since the speed of loading is insufficient. They do, however, indicate the resistance of the material to the propagation of a crack.

The tendency towards brittle fracture in a ferritic steel has little effect upon the results of a tensile test and none upon the hardness of the material, yet it is at once apparent in an Izod test, both by the low value of the energy absorbed and the appearance of the fractured surface. If the variation in energy absorbed is plotted against the temperature of testing, a curve of the type shown in Fig. 6 is obtained. If, in an isolated test, a fairly high energy value is recorded, this is not necessarily enough to indicate the suitability of the material for a given purpose. There is very little difference between the energy values of points A and B in Fig. 6, yet A is very near the transition range. Within the transition range itself pronounced scatter is often observed, and hence it is most important that the crack propagation resistance of the material should be known for the temperature range in which it is required to operate in service. A specification calling for a given minimum energy absorption at a certain sub-zero temperature is often good enough, but for particular applications it may be advisable to know the actual transition range.

Other factors must also be considered; cold work followed by ageing at normal atmospheric or slightly elevated temperatures may considerably raise the inherent transition range of the material. Irradiation produces a similar effect. Complex residual stresses, particularly in conjunction with stress concentrations, may result in triaxial stress systems which favour brittle fracture. Similarly, thick sections are more prone to failures of this type, both as a result of the general metallurgical characteristics of thicker materials and by virtue of the more complex stress systems which they can support.

The effect of irradiation is of increasing importance. The lanes of displaced atoms scattered by high-energy particles, and the tiny zones of extremely high transient temperature which accompany their deceleration may raise the inherent transition range of the material by a remarkable degree. It is in this type of application that the so-called impact test, sometimes supplemented or replaced by a notched bend test, is so valuable, since the tensile test is, in general, insensitive to these changes.

Fatigue

Although brittle fractures probably represent the most catastrophic and expensive of the structural failures which occur in service, the most numerous failures are associated with fatigue phenomena. The nature of the structural damage which accompanies prolonged cycling at comparatively low stresses is not yet completely known, so that our knowledge of fatigue effects is based entirely upon empiricism. A further difficulty arises from the scatter inherent in observed fatigue phenomena. The effect is sufficiently pronounced to warrant statistical treatment and this, combined with the fact that it is necessary to conduct tests to many millions of cycles and that the speed of testing cannot be increased very much above 5,000 cycles per minute without introducing other effects, further restricts the rate at which data can be collected for any particular material.

For the majority of steels and some non-ferrous alloys the S-N curve for alternating stresses of equal amplitude has the form shown in Fig. 7, and displays a limiting stress beneath which failure is unlikely within a duration of some hundreds of millions of stress reversals. It is a curious feature that the curve usually levels out to this endurance limit in from 10^5 to 10^6 cycles, and in the case of steel a pure fatigue fracture is extremely unlikely at more than 10^7 reversals. For steel, the endurance limit is usually 40-60 per cent of the U.T.S.

The majority of non-ferrous materials exhibit an S-N relationship of the type shown in Fig. 8, and there is no endurance limit, except in regard to a finite number of reversals. Precipitation hardening non-ferrous materials usually give this type of curve, and a distinguishing feature of such materials is the enormous scatter in experimental results.

In a corrosive environment steel ceases to exhibit an endurance limit and failure becomes inescapable in a finite time. But the speed of cycling is extremely important in corrosion fatigue. The corrosion process requires time and if the rate of stress reversal is fairly low the two phenomena combine to produce a rapidly growing crack. Two aspects of corrosion-fatigue phenomena which are often overlooked are the very minor amount of corrosion necessarily involved and the futility of combating corrosion fatigue with a material of higher tensile strength. The surface of a component which has failed by corrosion-fatigue need not show any evidence of gross corrosion and the only value in choosing a material of greater tensile strength (and therefore greater nominal fatigue strength) will lie in a slight increase in life, as shown in Fig. 9. If corrosion fatigue conditions have to be overcome, recourse must be made either to some means of effectively isolating the corrosive environment from the structure, or a corrosion-resistant material must be used, or else a finite life must be accepted. In the latter case there are obvious difficulties in estimating the life of the structure, particularly since in service the fluctuating stresses are rarely of equal amplitude, nor are the cycles repeated.

Tensile stresses are essential to the formation of fatigue cracks and residual compressive stresses can often be used to prevent their initiation, particularly since they usually

originate at a surface. An example is the effect of shot-peening and even shot-blasting. In the latter case, the resulting compressive residual stresses more than outweigh the stress concentrations introduced by the blasting operation. But caution is necessary in the application of such results, particularly to large structures and components or when axial loading is involved.

An illustration is given in Fig. 10 (a) in which a residual compressive stress (induced by rolling or peening, etc.) is used to reduce the subsequent peak surface tensile stress to an innocuous value. Fig. 10 (b) illustrates the way in which a similar technique applied to a component with a more gradual applied stress gradient will have very little effect upon the subsequent fatigue performance of the material.

A beneficial residual stress system may often be induced by deliberately overloading the structure. Consider a stress-concentration at the tip of a notch. A simple static overload of the structure to produce tensile yielding at the base of the notch will result in residual compressive stress at this position when the overload is removed. In this way the stress concentration at the notch may be minimised or even nullified. It is in this ability to redistribute peak stresses safely that the advantage of a conservative proof stress/tensile strength ratio lies. A typical example occurs in the case of I.C.E. big-end bolts in which material of tensile strength in excess of 70 t.s.i. frequently fails by fatigue initiated from very minor fretting corrosion damage at the surface. Replacement bolts in the same material heat treated to 65 t.s.i. have given long and uneventful service under the same conditions.

The question of surface finish is very important under fatigue conditions, and it should be borne in mind that there is a very definite risk in designing and building to a high order of material finish and physical properties, since any failure to meet the prescribed conditions in practice may be disastrous. Such considerations apply not only to the possibility of fatigue but also brittle fracture.

The author is grateful to the superintendent of the Admiralty Materials Laboratory, Poole, for permission to publish this paper; all views expressed are personal to the author.

ELECTROMAGNETIC BALL BEARINGS FOR INSTRUMENTS

ONE of the main advantages of gas lubricated or air bearings is that they can offer very low frictional losses. A recent development along rather different lines but offering a similar benefit may therefore be of wide interest. This is an electromagnetically-powered ball-bearing assembly now being made by the Barden Corporation of the U.S.A. It is intended primarily for precision instruments where the starting torque needs to be consistently equal to the normal running torque.

In operation, an electromagnetic device oscillates the outer ring of the supporting bearings and this action tends to cancel out the friction torque resisting the rotation of the supported member. It is claimed that this dynamic bearing makes available for the first time a self-contained ball-bearing assembly that closely approaches the minimum friction achieved by such delicate mechanisms as knife edges, jewelled pivots or flotation devices, and therefore applications may be expected in apparatus such as gyro gimbals, scales, balancing machines and other devices where a practical support bearing is required with inherent low torque qualities.

The four models available are designed for straddle mounting, but may be modified for flange, shoulder or cantilever mounting, and are rated for static loadings as in the table above.

Type (see Fig. 1)	Thrust lb.	Radial lb.	Outside dia. in.	Overall length in.
A	53	28	0·75	0·67
B	57	30	0·50	0·57
C	53	33	1·50	1·342
D	48	32	0·625	0·857

An electronic oscillator is required to power the electromagnetic unit and, since the oscillator draws less than one watt of power, the oscillator can be transistorised. The input terminals are located at one end of the bearing.

Without preload the running torque of the bearing is about one-tenth of that associated with a high quality instrument bearing, and under preload the running torque values are shown in Fig. 1; the extremely low values for pure radial loading with only moderately higher values for end thrust loading indicate the possibility of axially preloading the bearings to minimise mass shifts with only a moderate penalty of an increase in torque.

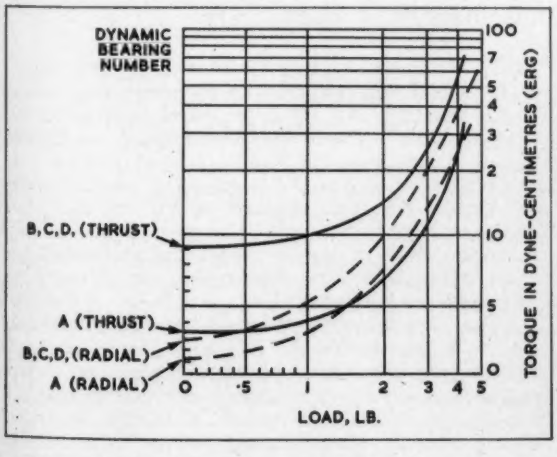


Fig. 1. Effect of bearing loads on the starting torque of electromagnetic bearings.

Fig. 2. Miniaturisation of bearing has been achieved with reduced restraining torque and good shock load capacity.

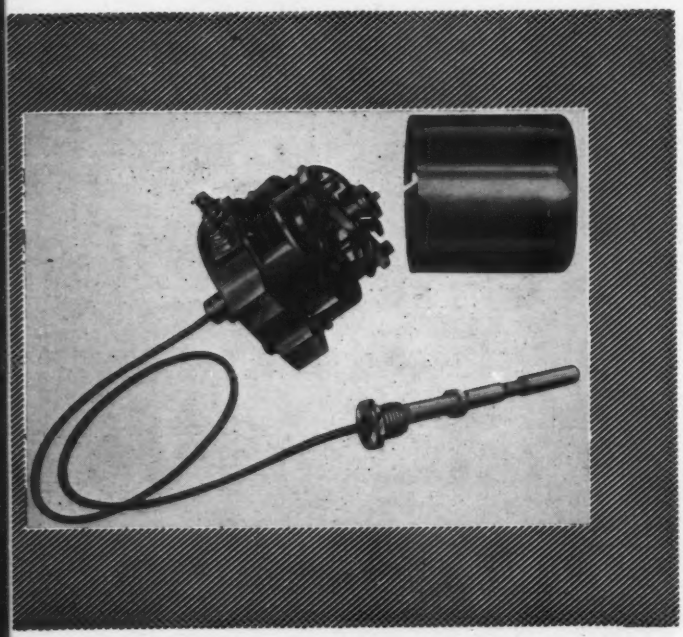
NEW IDEAS IN DESIGN

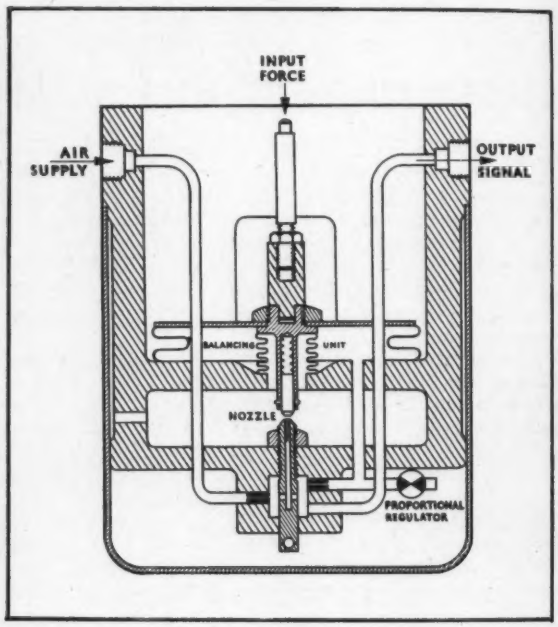
Outstanding products in current manufacture

Pneumatic Automatic Control System

IN place of the more usual electronic methods for "automatic watchkeeping", Cheltenham Auto Controls Ltd. have developed a device which uses compressed air. A force-balance pneumatic transmitter, which sends a signal by small-bore tubing to a distant indicating station, obviates the necessity for periodic inspection of instruments giving information on liquid levels, draughts, steam pressures, temperatures, flow rates, etc.

The instrument consists of the function-detecting input unit and a transducing element which converts the observation into a pneumatic signal. The transmitter uses hydraulically-formed bellows instead of rubber diaphragms, and so achieves unusual stability as well as robustness. The distantly located indicating panel also carries an interesting and novel arrangement of trigger relays. These may be set so that they trip when an incoming signal denotes approach to a danger limit, and their action causes an audible and visual alarm signal.





Camera Lens with Automatic Iris Diaphragm Mechanism

THE Synchronex-8 camera lens made by the Elgeet Optical Co. Inc. is fitted with a photo-electric device which, without any external power source, provides all the energy necessary for operating the diaphragm mechanism which it obtains from the light in the picture area. The photo-cell used is of the self-generating type, and is claimed by the manufacturers to last a lifetime if treated with care. This is ensured by the sealed construction of the iris mechanism which is claimed to prevent oils within the camera, atmospheric spray, fumes, etc., from interfering with the lens performance.

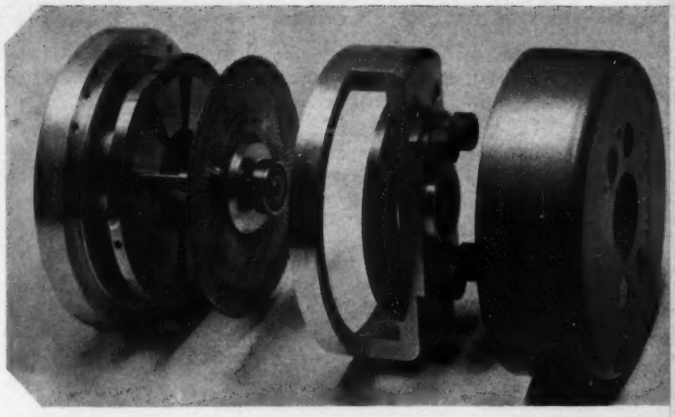
The lens, which has been developed for use with 8-mm. cameras, is provided with an always visible low-level light indicator. When there is insufficient light for colour work, an indicator needle dips into a shrouded, translucent dome which projects from the side of the lens barrel.

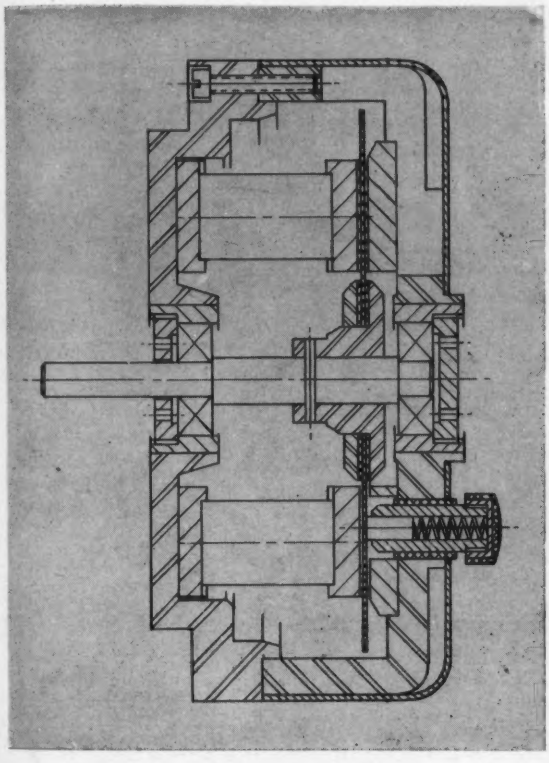
A full range of manual settings, from f/1.8 to f/16, is available for special photographic applications, such as stop-motion, slow-motion and high-speed effects.

Unique Advantages Claimed for Printed-circuit D.C. Motors

A RANGE of printed-circuit electric motors recently announced by Societe d'Electronique et d'Automatisme is claimed by the manufacturers to possess many advantages and to be suitable not only for general service applications but also for the instrument, servo and control fields. A wide horsepower range from a few watts to several kilowatts is said to be possible. From the manufacturing standpoint, the motors are stated to be easier to produce than the conventional type of machine, the components being easy to manufacture and assemble.

The armature is a thin disc, perforated with a large central hole and mounted on its shaft by means of suitable bearing flanges. Flat, ribbon-like copper armature conductors are produced by the printing process on each face of the disc. The curved portions of conductors, near the edge and centre of the disc, are connected to corresponding curved sections on the opposite face. The entire group of conductors so connected constitutes the printed circuit equivalent of a multi-polar wave winding as found in conventional machines. The armature produced in this way is mounted in a planar air gap so that the straight radial portions of each conductor lie within the field flux. For most machines a separate commutator is not necessary, low drop silver-graphite brushes making direct contact with the bare surface of the armature conductors.





Many advantages are claimed for these motors:

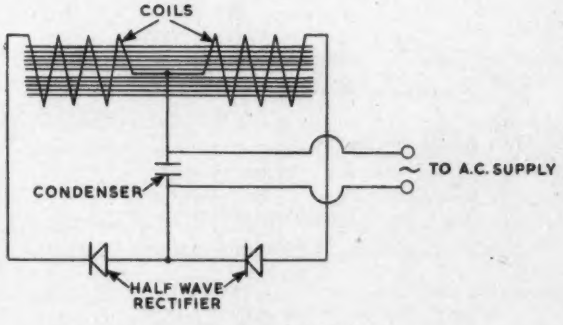
They have extremely low intrinsic armature inertia. Smaller machines may be designed to make fifty complete starts and stops per second. They are well suited for direct drive in servo applications. They possess negligible armature reactance, as the rotating portion of the machines contains no iron. Extremely smooth commutation; owing to the large number of commutator segments, absence of armature reaction and the form of the armature windings, the torque is completely free from "cogging" at any speed. The motors are suitable for high-temperature operation, as all active armature conductors are uninsulated. The base material for the printed winding may consist of glass or other ceramic compositions. Provision for internal damping for special applications may be furnished, with an internal damping torque proportional to speed, at small cost. They have low internal impedance; the machines are ideally suited for operation with power transistors. The planar air gap construction lends itself to "pancake" shapes.

Novel Air Compressor Has No Air Reservoir

A SMALL twin-cylinder air compressor, recently developed by Grange-Camelon Iron Co. Ltd. for use with small power tools and spray guns, has two axially-opposed pistons operated by the reciprocation of a central armature.

Among the advantages claimed for this unusual design is that an air reservoir is not necessary, as the stroke length of the armature automatically increases to meet the demand of increased output requirement. From the production standpoint, the design would seem to offer notable advantages in that the component parts are either simple pressings or turned and bored pieces which can be easily assembled.

Until now the stroke length of electric-magnetic motors has been relatively short and the movement of a vibratory



WIRING DIAGRAM

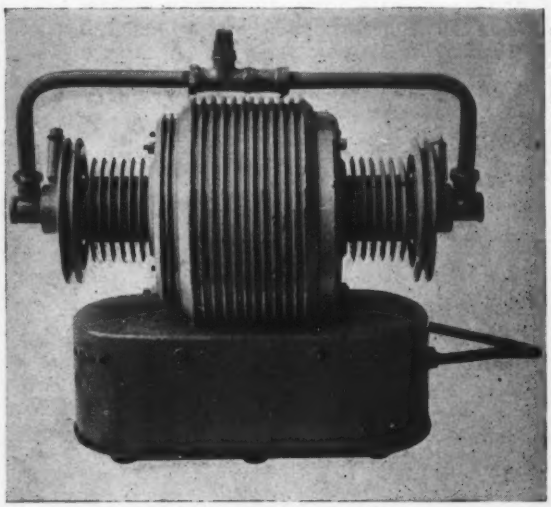
character only. The length of stroke of the Grange-Camelon motor is considerably longer, up to 2 in. or more. From the wiring diagram it will be seen that the terminals of the motor are connected to a source of a.c. supply. A source of pulsating current is produced in each of the two field coils due to two rectifiers to which the a.c. supply is connected, each coil being energised alternately. Mutual induction between the energised coil and the non-energised coil at any instant causes a back e.m.f. to be induced in the non-energised coil in opposition to the supply voltage. This reduces the resisting voltage required by the rectifiers whereby the number of plates in each rectifier is reduced in comparison with the number which would be required to resist the full voltage of the supply. A d.c. supply can be used for the motor, provided a suitable interrupter is provided.

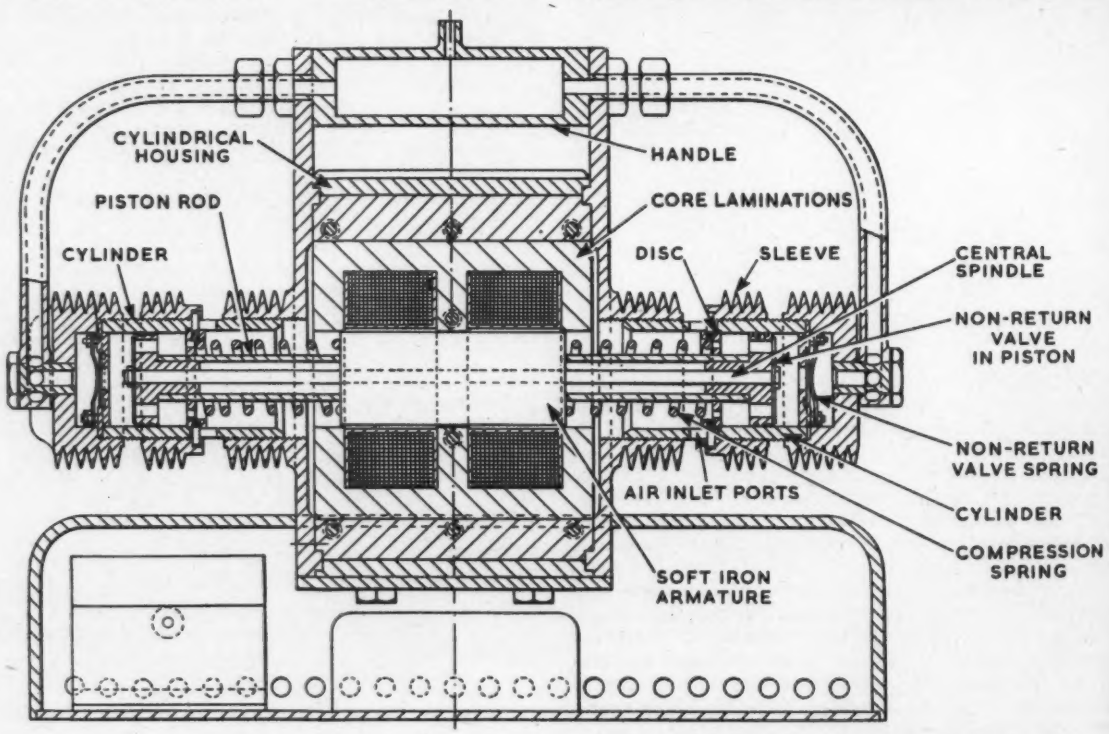
The central core laminations, which are held between two side plates by riveted construction, are bored to receive a soft iron armature through which passes a central spindle. Nuts on the end of this spindle serve to retain the two pistons, which are spigoted into two tubular piston rods, and also to retain the non-return valves which occlude ports in the piston.

A perforated flanged disc through which the piston rod passes serves to constrain a helical coil spring which bears at one end against the disc and at the other end against the soft iron armature. Adjustably screwed on to each cylinder is a sleeve which bears on radially projecting pins carried by the flange disc, mentioned above, and extending through axially elongated slots formed in the cylinder. By rotating the sleeve on the cylinder, the disc, through the pins, can be adjusted to alter the compression in the spring.

During reciprocation of the armature, on the inward stroke of a piston, air is drawn through the inlet ports in the side walls of the cylinder and then through ports in the disc and piston. On the outward stroke this air is compressed in the cylinder head and passed through the non-return valve in the cylinder head and thence via a banjo to the hollow handle to which the outlet branch is fitted. For efficient operation it is essential that the natural frequency of the armature assembly be adjusted to be equal and in phase with the frequency of pulsation of the flux, whereby at full output a condition of near resonance is achieved.

The prototype of this compressor, which has now completed the development stage, has an output of 6½ cu. ft./min. at 60 p.s.i. (gauge).





In the July edition of "New Ideas in Design", the Tangye Hydraflo pump was inadvertently described in the heading as a "Waste Pump". This should have read "Water Pump".

IMPROVING WEAR RESISTANCE BY HARDFACING BY WELDING

Hardfacing by welding of components and machine tools subjected to heavy wear is being used increasingly in this country and abroad. This article discusses the best alloys and welding processes applicable

by E. N. GREGORY, A.I.M.*

HARDFACING by welding is used to deposit a wear-resistant alloy on either a worn component or a new component that is to be subjected to wear during service. This is usually simpler and more economical than making a whole component out of a wear-resistant alloy, for hardfacing with one or two layers of weld metal provides the advantages of a wear-resistant surface with those of a tough backing material. Reclamation can be carried out again when the weld has worn away by deposition of a small amount of wear-resistant alloy at the place where it will be most useful.

Occasionally there are advantages to be gained by making a whole component from a wear-resistant alloy, and in many cases this is the only convenient method for making parts accurate to close tolerances. Parts of certain pumps used for handling abrasive materials are cast in wear-resistant alloys, their shape being too complicated to be hardfaced by welding. Extrusion dies are made by precision casting high cobalt alloys and wire-drawing dies may be made by sintering tungsten carbides. The manufacture of such components by hardfacing softer base metals and subsequently machining and grinding to shape is impractical. Other parts of extrusion presses, apart from the dies, require high wear resistance, and such parts as extrusion containers and mandrels are hardfaced by welding using the same high cobalt alloys that are used for casting the dies.

In such industries as agriculture, mining, oil well drilling and earth moving, typical examples of equipment that lend themselves to protection by hardfacing are ploughshares and harrows, coal picks, drill bits and collars, digger teeth, bulldozers and rock drills. Hardfacing an excavator bucket, as shown in Fig. 1, extends its life from about six months to two years.

Most hardfacing deposits can be shaped, if necessary, by one or more of the following methods: machining with high-speed steel or carbide-tipped tools, grinding and forging. Components that have to be true to shape include the large variety of knives that are used in various industries—for shearing hot billets, for trimming the pile of carpets, for cane, bean, ensilage slicing and pulping.

Most of the common welding methods are currently used in hardfacing. Originally, oxy-acetylene welding was used in the majority of applications, but now the greatest tonnage is deposited by the metallic arc process with coated electrodes.

However, in spite of the relatively low speed of gas welding, hardfacing by this method will continue to find favour for the deposition of the more expensive hardfacing alloys, where the minimum of dilution by parent metal is desirable, and the speed of this process is increased by the use of jigs that position and rotate the work while welding is carried out manually.

The use of automatic welding by submerged or open arc processes has been applied extensively to hardfacing in the U.S.A. and no doubt will increase in this country. Development work has also been carried out in the application of the gas-shielded welding processes to hardfacing, and many ingenious uses for these methods have been found, for these processes lend themselves to mechanisation.

Wear is caused by many factors, the chief ones, acting separately or in combination, being abrasion, impact, erosion, heat and corrosion. Corrosion is rather a special type of wear and while many hardfacing deposits are expected, and indeed are designed to resist corrosion, many corrosion-resistant alloys deposited by welding for the purpose of protection do not come under the heading of hardfacing alloys. A large variety of alloys are deposited solely for their corrosion resistance, but these will not be considered in the present article.

* *Development officer, British Welding Research Association.*

Fig. 1. Excavator bucket for limestone hardfaced by metallic arc welding with an alloy steel deposit. (Photo: Murex Welding Processes Ltd.)

Hardness and Wear Resistance

It is convenient to consider first the difference in wear resistance between normal constructional steels and hardfacing alloys.

Much confusion of thought exists over the relationship of wear resistance to hardness; it is commonly thought that the harder an alloy is, the longer it will last when subjected to wear in service. This belief arises from the fact that, under conditions of simple abrasion, it is usually found that the highest wear resistance is obtained by using the hardest available hardfacing alloy. However, a hardfacing alloy having a hardness of, say, 450 V.P.N. will have a service life five to twenty times that of an alloy steel not specifically designed for hardfacing, even though the alloy steel may be heat treated to have a hardness of, say, 800 V.P.N.

The heat treatment of the alloy steel, however, will increase its resistance to simple abrasion over that of the steel in the annealed condition. It is also true that if the hardness of a hardfacing alloy is increased by heat treatment, then this will usually increase the wear resistance under conditions of simple abrasive wear.

Simple abrasion may be defined as wear caused by abrasive particles sliding over a surface under low stresses; practical examples are sand sliding down a chute or a mechanical shovel digging in loose sandy soil. Under such conditions the wear resistance of any particular alloy seems to be related to its hardness which may be increased by heat treatment, but when various alloys are considered a soft one may show greater resistance to wear than a hard one, due to differences in inherent wear resistance.

The introduction of impact removes the emphasis from hardness and lays it on toughness. Toughness is inversely proportional to hardness, so that the harder hardfacing alloys will not serve well under conditions of heavy impact.

Combinations of abrasion and impact are resisted by various alloys, which range from soft ones having low abrasion resistance and high impact resistance to hard alloys having a small measure of impact resistance. Intermediate alloys have useful combinations of resistance to both abrasion and impact.

As stated above, some correlation seems to exist between hardness and low stress scratching abrasion. However, under conditions of high stress grinding abrasion that occur, for instance, when using a grindstone, a hardened alloy steel usually has lower abrasion resistance than the same steel in the annealed condition. Similarly, under these circumstances a heat-treated alloy steel hardfacing deposit may show lower abrasion resistance than when it is in the as-welded condition. On the other hand, a high chromium martensitic iron shows improved resistance to high stress grinding abrasion when hardened by heat treatment.

It will be appreciated that the selection of the most suitable hardfacing rod and the question of whether to heat-treat the deposit depends upon the precise factors that cause wear in each particular case.

Often it is fairly simple to select the most suitable rod, and the principles underlying selection are discussed later in this article. However, when it is difficult to analyse the factors causing wear, it is best to rely on the accumulated experience of manufacturers of hardfacing rods.

Classification of Hardfacing Rods

Hardfacing rods may be classified into four groups (see Table 1), their general characteristics being given below:

1. Iron-base Containing Less Than 20 per cent Alloy Additions—These iron-base alloys contain, in addition to carbon, varying amounts of chromium, manganese, nickel, and sometimes smaller additions of boron, tungsten or molybdenum. Molybdenum, manganese and nickel promote hardening of the steel, and chromium and molybdenum are pronounced carbide-forming elements. Chromium is common to most of the hardfacing alloys, as chromium carbide is one of the most wear resistant of carbides, coming second only to tungsten carbide. The chief function of the alloying elements is to control the microstructure produced, which is usually martensitic or bainitic with uniformly distributed chromium carbides.

Group 1 alloys are characterised by low cost, wear resistance at least three times as great as that of a heat-treated medium carbon steel, and high impact resistance. Within the martensitic alloys of the group the abrasion resistance increases and the impact resistance decreases with increase in hardness.

The deposits having hardnesses under 300 V.P.N. are readily machinable, but harder deposits require special tools and in some cases can only be shaped by grinding. It is sometimes possible to soften a deposit by heat treatment, carry out the machining operation, and then reharden afterwards.

The compositions, microstructures and properties of group 1 alloys will vary somewhat according to the base metal being surfaced and the number of layers of weld metal deposited. Typical applications of these rods, one of which is illustrated in Fig. 1, are the hardfacing of crushing machinery, gears, dies, railway points and crossings, and ballast tamping bars.

The martensitic stainless steels containing about 12 per cent chromium have increased heat and corrosion resistance. Chromium has a high affinity for oxygen, and at room temperature an impervious invisible film of oxide is formed on the surface and affords protection from corrosion in certain circumstances. The uses of these alloys vary, depending upon the chromium and carbon contents which range from 10-14 per cent Cr and 0·1-1·0 per cent C. Applications include hardfacing of valve seats, gear wheels, rolls and tools subject to impact.

The 14 per cent manganese steel is mainly austenitic as deposited, having a hardness in the region of 200 V.P.N. Under conditions of impact in service, work hardening takes place, and the hardness at the surface may increase to 550 V.P.N. This extremely tough alloy has very high resistance to heavy impact, and has many applications in the industries of construction, mining, quarrying, oil-well drilling, etc. It is used to protect components that handle heavy materials, such as rock crushers, grinding mills and mechanical shovel buckets, and is also applied to railway points and crossings.

Both group 1 and group 2 contain two rods suitable for tipping tools, and these can be used to make a wood or metal cutting tool at least as good as a high-speed steel tool, by depositing a bead of weld metal on the end of a mild steel shank and grinding to shape.

2. Iron-base Containing More Than 20 per cent Alloy Additions—The usual alloying conditions are chromium from 18-35 per cent manganese, silicon, molybdenum, cobalt, vanadium, tungsten and nickel, giving a total alloy content of 25-50 per cent. This group includes martensitic alloys, high chromium austenitic steels and irons and high-speed steels.

In general, the martensitic alloys are characterised by higher abrasion resistance and corrosion resistance, but usually have lower impact resistance than group 1 martensitic alloys. Wear resistance is maintained at elevated temperatures.

Austenitic steel weld deposits containing 18 per cent chromium and 8 per cent nickel have an initial hardness of 200 V.P.N., but the deposit work hardens considerably under stress.

Fig. 4 shows a typical application of high chromium austenitic iron hardfacing rods, used in this case for protecting the leading edges of a steel gravel pump impeller.

TABLE I. Classification and composition of hard-facing rods.

Description	Typical Composition									V.P.N.	Deposition Method
	C	Cr	Mn	Mo	V	W	Co	Ni	B		
Iron-base containing less than 20 per cent alloy additions (Group 1)											
Carbon steel	0·5									250	O.A.
Martensitic alloy steel	0·1	1	0·7							250	Arc
" " "	0·1	3·5	1							350	Arc
" " "	0·25	1·0	1	0·3						350	Arc
" " "	0·35	3	1							450	Arc
" " "	0·45	5		5	0·75					650	Arc
Martensitic stainless steel	0·10	12								400	Arc
" " "	0·25	13								450	Arc
High-speed steel	0·3	1·5	1			7·5	2			500	Arc
Tool steel	0·8	4		8	1	1				650	Arc
Austenitic manganese steel	1·3		14							200–600	O.A., Arc
Iron-base containing more than 20 per cent alloy additions (Group 2)											
High-speed steel	0.35	4.5				18				600	Arc
Tool steel		10				15			2.5	750	O.A.
Austenitic steel	0·1	18		3				8		200–500	Arc
Austenitic iron	5	32	4							700	O.A., Arc
Martensitic iron	2·5	28	1							600	O.A., Arc
Non-Ferrous (Group 3)											
Cobalt base	1	25				5	55			400	O.A., Arc
"	2·5	30				13	45			600	O.A., Arc
Nickel base		18						70	4	650	O.A., Arc
Carbides (Group 4)											
Tube carbide	50–60 per cent tungsten carbide, 40–50 per cent iron									Carbide granules over 1,800	O.A.
										Homogeneous deposit over 1,000	Arc

3. NON-FERROUS—The most well-known alloys in this group are those based on the ternary system cobalt-chromium-tungsten. Small additions of other elements are often made. Cobalt endows the alloys with hot hardness, and chromium and tungsten bring about appreciable secondary hardening. Other alloys in group 3 are based on nickel chromium alloys containing 60-80 per cent nickel and 10-30 per cent chromium, with minor additions of carbon, boron, iron and silicon.

The non-ferrous hardfacing alloys have excellent wear resistance and outstanding properties at elevated temperatures. Corrosion resistance is comparable to, and in some instances superior to, that of stainless steels. Typical applications are the surfacing of internal combustion engine and steam valves, rolling mill guides, hot billet shears and hot metal tongs. Their use is not restricted to high-temperature applications, for they are used most successfully in every industry in which wear is a problem.

Fig. 5 illustrates a typical application and shows the deposition of a cobalt-chromium-tungsten alloy.

4. CARBIDES—Hardfacing rods for metallic arc or oxy-acetylene application consist of steel tubes filled with tungsten carbide particles, sometimes having minor additions of carbides of tantalum or titanium, together with binding agents and flux.

Oxy-acetylene welding produces a heterogeneous type of deposit, consisting of tungsten carbide particles in a matrix of alloy steel containing secondary carbides of iron and tungsten, due to slight diffusion of tungsten from the carbide particles.

In deposition by the metal arc process, the intense heat of the arc melts most of the tungsten carbide, even when large particles of carbide up to 10 mesh size are used. The structure is homogeneous and consists of alloy cast iron having a hardness in excess of 1,000 V.P.N. The main characteristics of the carbide deposits are exceptionally high abrasion resistance and good hot hardness. Typical applications are coal cutter picks (see Fig. 3), rock drills and ploughshares.

Selection of Hardfacing Alloys

The factors causing wear must be considered before selection of a suitable hardfacing rod can be made. To illustrate this point, the main alloys occurring in Table 1 have been assembled horizontally in Fig. 2 in order of increasing abrasion resistance from left to right (which gives the decrease in impact resistance) and vertically down in order of increasing resistance to heat and corrosion.

A chart such as this has strict limitations, as there will be variations in corrosion resistance between alloys in each horizontal line, and, similarly, vertical lines will not necessarily intersect alloys having comparable abrasion or impact resistance.

It would be possible to enter every known hardfacing alloy on such a chart, but the precise conditions of service would have to be stated, since the alloys would have different positions on the table under different conditions. Such conditions might vary from heat plus heavy impact to corrosion superimposed on high stress grinding abrasion. In these two examples of numerous possible conditions, there would be further variations depending on the precise service temperature and the nature of any corrosive medium present. Despite these limitations, certain general principles underlying the selection of a suitable hardfacing alloy have been indicated.

For various combinations of abrasion and impact in the absence of heat and corrosion, the low-priced martensitic

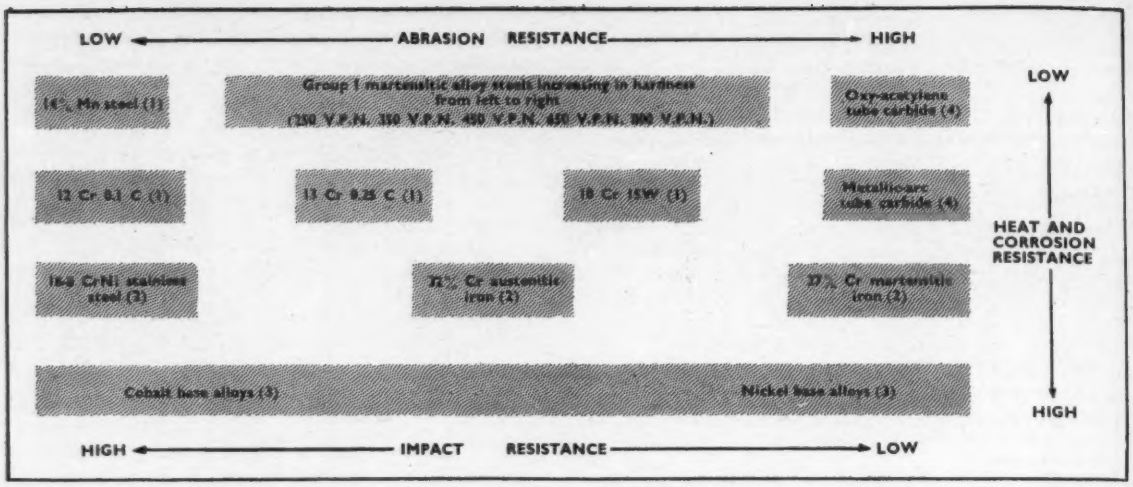


Fig. 2. Comparison of properties of principal alloys given in Table 1. Bracketed figures indicate group to which alloy belongs.

Fig. 3. Coal cutter picks hardfaced on the tips with oxy-acetylene deposits from tube carbide rods containing a special grade of tungsten carbide. (Photo: Murex Welding Processes Ltd.)

alloy steels of group 1 give excellent service, the harder alloys having higher abrasion resistance and lower impact resistance. In the top line of Fig. 2 the highest abrasion resistance is provided by oxy-acetylene deposits of tube carbide.

The higher the alloy content of martensitic steels, particularly as regards chromium, the higher is the resistance to softening on heating. The oxy-acetylene deposited carbide is also resistant to softening, so that the heat resistance of the alloys in the top line increases from left to right, but this feature is not indicated by the table.

The 14 per cent manganese steel, which comes at the left due to its exceptionally high impact resistance. does not soften on heating, but is embrittled due to precipitation of carbides, and may therefore be said to have poor heat resistance.

Tube carbide rods deposited by the metallic arc process produce more or less homogeneous deposits, particularly in single layers.

The resultant tungsten alloy steel or iron has slightly lower abrasion resistance than oxy-acetylene deposited carbide, but because of the higher alloy content of the steel or iron, the corrosion and heat resistance are increased. Thus the rod is placed in the second horizontal line of Fig. 2, together with the 12 per cent chromium stainless steels whose heat and corrosion resistance are higher than those alloys mentioned above.

The cobalt-base and nickel-base alloys have the highest heat and corrosion resistance and come in the bottom line of Fig. 2. Both groups contain a range of alloys which may have extremely high abrasion resistance or high impact resistance, depending on the composition, so that there will be considerable overlapping of the groups. The wear resistance of these alloys will also depend on the conditions of service, such as type of atmosphere encountered, and the correct choice of alloy should be left to the suppliers, who have built up a wide experience of applications over many years.

Extensive use is made of 18-8 chromium-nickel steel for surfacing mild-steel turbine blades to provide erosion resistance. Its impact resistance is high and it work hardens in service, although it is not as good as 14 per cent manganese steel for resistance to heavy impact. Perhaps the widest use of 18-8 stainless steel in hardfacing is for a buffer layer between hardenable steels or cast iron and the group 1 martensitic alloy steels. It is also used as a buffer layer between 14 per cent manganese steel base metal and weld deposits of 14 per cent manganese steel, in order to prevent the formation of a brittle zone at the manganese steel weld-base metal junction.

Also in the third horizontal line of the chart are found the martensitic and austenitic stainless irons. The variation in composition of these stainless irons affects the microstructure, which contains chromium carbides in a matrix that may consist of soft austenite, hard martensite, or mixtures of the two. For low stress abrasion of the type met by agricultural machinery in sandy soil the austenitic iron is suitable, the composition being adjusted to provide a large volume of hard wear resistant carbides For high stress grinding abrasion the grade having a martensitic matrix is found to be more satisfactory, and heat treatment gives a further improvement.

It is surprising that the stainless irons have not been more widely used in this country, for under certain conditions their wear resistance is comparable with that of the more expensive non-ferrous or tube carbide rods and their price is considerably lower.

This consideration of cost is, of course, most important in the selection of hardfacing alloys. The achievement of the greatest wear resistance at the lowest price requires the consideration of many factors, such as the cost of a whole new component, down time for replacement by renewal or by hardfacing, cost of various hardfacing rods and the life of the different weld deposits before repair becomes necessary. This type of information should be

collected by those firms who carry out hardfacing extensively, for by constantly changing techniques many savings can be made.

Recent Developments

The extensive study of wear resistance by laboratory tests and field trials has increased knowledge of the process of wear and has indicated the best methods of combating it. New wear-resistant alloys are being made all the time, and hand in hand with this development has gone the development of welding processes, which in the last few years has had a considerable effect on hardfacing.

In the past when there were three basic manual processes—oxy-acetylene, metal-arc and carbon-arc—the choice of a suitable rod and process was much narrower than it is now with the numerous automatic processes available. The use of automatic welding in the fabricating industries, such as shipbuilding, advanced in applications where it showed increased speed without sacrifice of efficiency, and economies in skilled labour. Hardfacing is very much concerned with economies, its basis being the reclamation of components that would otherwise be scrapped, and also these components remain in continuous service for longer periods, thus reducing shut-down times for repair. Any welding process that decreases the time required for reclamation or maintenance will be attractive to those who use hardfacing.

Recent developments in welding processes applied to hardfacing have been widespread, and the brief references given below summarise only some of the chief developments.

OXY-ACETYLENE WELDING—The use of jigs and positioners that move or rotate the work while hardfacing is carried out manually has been mentioned. The development of mechanised oxy-acetylene welding heads, sometimes carrying multiflame burners which considerably speed up the process, have been found useful for certain applications. In this process the filler wire is fed automatically by means of guide rolls.

METALLIC-ARC WELDING—Perhaps the most important recent development is the use of basic coatings for hardfacing electrodes, which reduces the tendency for cracking of hardenable base materials and increases the soundness of weld deposits, particularly when deposited on certain steels.

AUTOMATIC OPEN-ARC AND SUBMERGED-ARC PROCESSES—These processes use a continuous coiled electrode. The brittleness of many hardfacing alloys prevents their production in coil form, and this has promoted the development of composite electrodes in which powdered alloys and flux are contained in a continuous flexible steel tube, or a mild or alloy steel core wire surrounded by thin, spirally wound wires, which anchor an extruded flux coating.

A method that restricts dilution to below 10 per cent is the use of multiple electrodes in series. By using two or more converging electrodes connected in series, the welding current flows from one to the other via the "series-arc". Thus, low heat input to the base metal gives low penetration and dilution with high deposition rates, minimum heat-affected zone and minimum carbon loss.

Recent developments in submerged-arc welding include the use of plain carbon or alloy steel wires, with alloy-enriched submerged-arc fluxes.

The application of a vibratory motion to the welding head has been introduced to many automatic welding processes for hardfacing. This spreads the weld deposit and reduces dilution by the base metal.

INERT GAS-SHIELDED ARC PROCESS—Both the argon tungsten arc and gas-shielded metal-arc processes have found applications in hardfacing.

One of the most interesting applications of argon tungsten arc welding is hardfacing components with an overlay of tungsten carbide, which is introduced into the molten puddle in the form of granules through a tube. The process is fully automatic and is faster than oxy-acetylene welding, and the carbide granules do not melt as in metal-arc welding.

In the inert metal-arc process, a recent development is the introduction of an auxiliary wire into the molten weld, from the side which melts without passing through the arc. This "cold wire" reduces the temperature of the weld pool, thus restricting dilution and increasing the rate of deposition of metal.

Many of these developments were pioneered in the U.S.A., where industry has been hardfacing-conscious for many years and quick to put developments into practice. There is no doubt that these developments will eventually be available in the U.K., since many prospective users of the processes are anxious to apply them. The importance of hardfacing is recognised in the U.S.S.R., where rapid advances in its use are foreseen. Recent reports from Russia on the next seven-year plan for industry include figures for the expected yearly consumption of hardfacing alloys; automatic welding processes are expected to account for about 45 per cent of the impressive total.

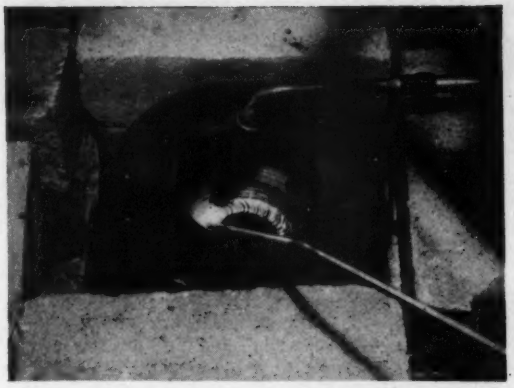


Fig. 4. Manganese steel 8-in. gravel pump impeller faced with arc deposits of a high chromium austenitic iron in a lattice pattern.

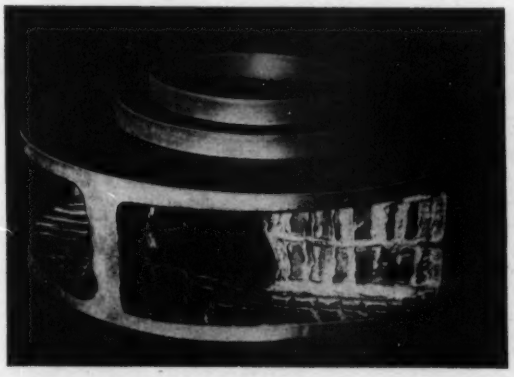


Fig. 5. Depositing a cobalt-chromium-tungsten alloy on the internal seat of a 4-in. molybdenum steel globe valve body used on high-temperature, high-pressure steam. A preheat temperature of 300-350 deg. C. is provided by town gas burners and maintained during deposition by surrounding with fire bricks. Normalising and machining and grinding are carried out after welding. (Photos: Deloro Stellite Ltd.)

designer's notebook

Bearing Screw Provides Planetation and Freewheeling

THE Roton anti-friction bearing screw, in addition to providing means for converting rotary to linear motion and vice versa, is claimed by the U.S. manufacturers to possess in certain applications a number of design advantages over bearings of the recirculating ball type.

Fig. 1 shows the elements of the screw. A series of dumb-bell-shaped bearing units (or Rotons, as they are called) are spaced and caged between the lead screw and the annularly grooved nut, which serves as the outer race. As the nut and the screw are rotated relative to each other, the Rotons engage both. It will be seen that, as long as the cage is free to rotate about the axis of the lead screw, each Roton will rotate about its own axis while simultaneously rotating relative to the lead screw axis, thus providing an epicyclic friction drive. This planetary motion results in a mechanical reduction of the linear advancement per revolution that would be expected if the pitch of the lead screw were considered alone. This feature, which is employed only for certain applications, is available either for speed reduction or mechanical advantage, or both.

Different versions of the bearing screw are available for various types of duty. For cases where the relationship between linear advancement per revolution need only be approximate, as would be the case, say, in the operation of a car window, the planetary feature mentioned above would be employed. An advantage claimed is that the non-positive drive to the nut (or lead screw) eliminates repetitive tooth loading in the gear drive to the screw. A notable feature of this type of bearing screw is that the problem of nut-jamming at the end of the stroke is avoided, together with the need for accurately positioned limit switches. Figs. 3 and 4 show how this is achieved. The Roton cage extends beyond the nut and is provided with dogs. When the nut reaches the end of its travel on the lead screw, one of these dogs (C) engages a stop pin (P) fitted in the lead screw and projecting from its side a short distance. This effectively prevents further rotation of the cage and planetation of the Rotons (R). When this occurs the Rotons no longer tend to climb the screw helix and merely freewheel on their axes until reversal occurs. This type of bearing screw is provided, in standard assemblies, with internal trunnion mounts.

For applications where a positive linear advancement with a minimum of backlash is required, another version of the bearing screw is available (see Fig. 2). In this type the cage is the load-carrying member and can be adapted to rotary loading to ensure accurate linear advancement with minimum friction. The manufacturers claim that with this type of assembly two or more units used in tandem will advance at the same rate. Freewheeling at the end of the stroke is not a feature of this type.

A standard range of Roton assemblies is available to suit a large number of load and linear movement requirements. These applications include the movement of car windows, seats, convertible hoods and luggage compartment doors, hospital beds, materials handling equipment and folding doors. It would appear that, when used for linear to rotary conversion, they would be particularly suitable for use in valve operating gear in conjunction with air or hydraulic actuators.

In addition to the numerous types of application for which the manufacturers of these bearing units have provided assemblies, there still exist special cases in which modified assemblies might be devised for special applications. Examples of instances where it is necessary to move platens through fixed distances, with provision for reversal, occur frequently in automation set-ups and special tooling. For such applications the reduced friction of units of this type, taken in conjunction with the fact that limit switches are not necessary, would appear to offer distinct advantages over the conventional acme screw and nut.

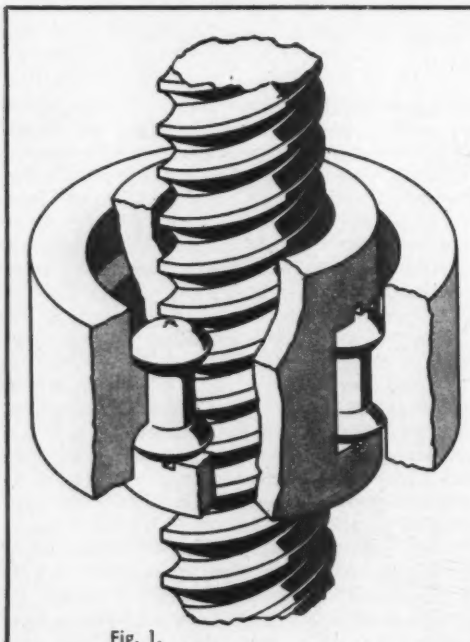


Fig. 1.

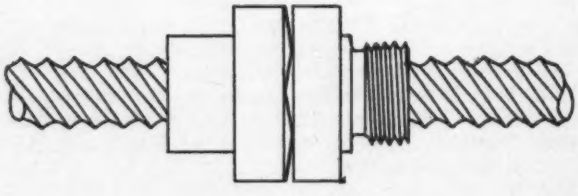


Fig. 2.

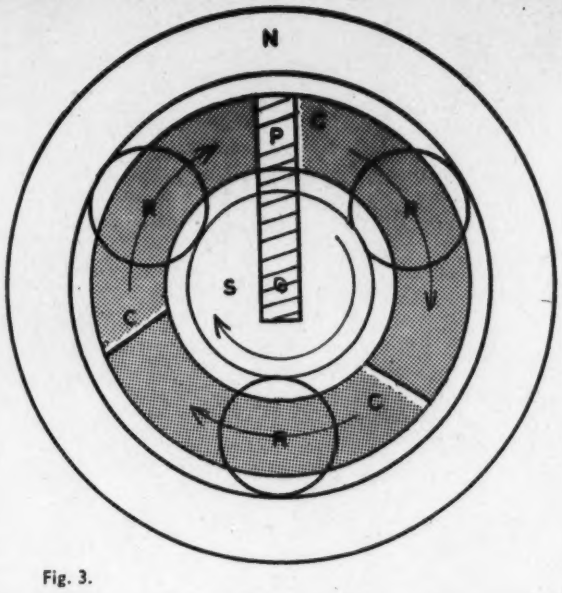


Fig. 3.

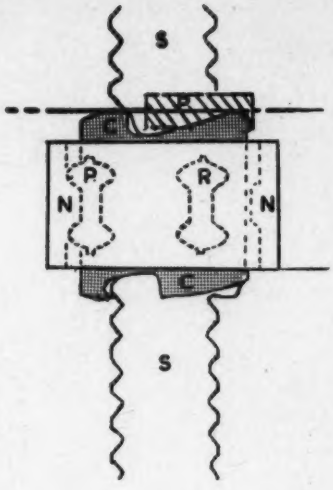


Fig. 4.

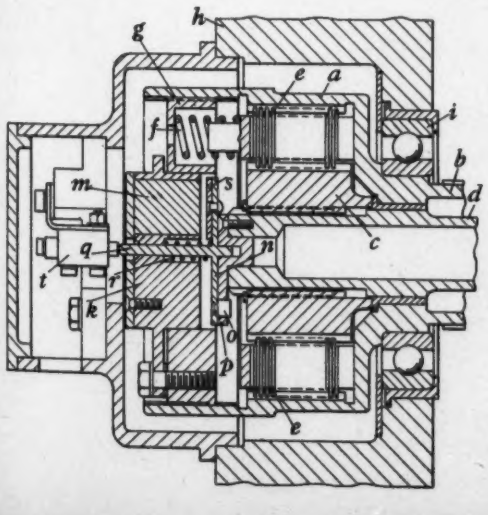
A Slip Detector for Friction Clutches

A TYPE of patented power-transmitting clutch for many different types of application, but particularly intended for use in conjunction with the type of actuator used in an aircraft, for operating an undercarriage or other similar moving part, where it is important for the pilot to know whether or not the actuator is functioning correctly, is illustrated in the drawing below.

The clutch comprises an annular part (a) formed on or secured to an input member (d), the parts (a) and (c) being interconnected by annular friction plates (e). The latter are loaded by a number of equi-spaced springs (f), the springs being carried by a part (g) secured to the part (a). The clutch is contained within a housing (h) and is supported by a bearing (i).

The detector includes a member (k) secured to the part (g) of the clutch. The member (k) carries a permanent magnet (m) situated at a convenient radial distance from the rotation axis of the clutch. The other member of the detector consists of a disc (n) which is connected by a pin (o) to a part (p) secured to the output member (d) of the clutch. The disc (n) is supported with axial freedom of movement by a spindle (q), one end of which extends through the detector member (k), the other end being supported in the part (p). A spring (r) on the first mentioned end of the spindle (q) serves to urge the disc (n) away from the part (k). Also on the disc (n) is secured a salient and an eccentrically placed iron pole piece (s). The end of the spindle (q) acts on a micro-switch (t) mounted within the clutch housing and adapted to control an electric circuit associated with any convenient signalling means.

When slip occurs, with relative rotation of the two members of the detector, the axially movable member (n) is intermittently attracted by the magnet, so causing an intermittent signal to be given. When no slip occurs, the signal remains dormant or is continuously active, according to the position occupied by the pole piece (s) on the disc relative to the magnet. *Rotax Ltd.*



CONTRIBUTIONS INVITED

Readers are invited to submit for publication in "Designer's Notebook" details of ingenious devices and mechanisms which could be used more widely than in their original application.

Contributions, which will be paid for, should preferably be about 300 words in length and be accompanied by an explanatory diagram or sketch. The designer's name will be published, unless requested otherwise.

Contributions should be sent to The Editor, "Engineering Materials & Design", Drury House, Russell Street, London, W.C.2.

DESIGNING FOR SHELL MOULDINGS

Shell mouldings can offer the designer precision castings in a variety of metals at high production rates. The characteristics that can be achieved, together with the possibilities and limitations of the process, are outlined here

by N. WALKER*

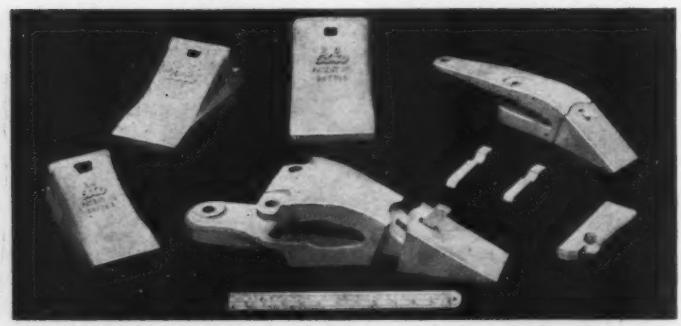
THE shell moulding process for the production of castings has been in operation in this country for about ten years, during which time the volume and variety of castings produced have grown rapidly.

The process makes use of a moulding material comprising a suitable grade of sand, usually silica, bonded with a phenol-formaldehyde resin, the two constituents being intimately mixed in the dry state. By allowing this mixture to fall into contact with a heated metal pattern plate, the heat causes the resin to flow and thus bond the grains of sand together. This action forms a thin, partially cured layer over the surface of the pattern. The thickness of this layer can be controlled by the length of time that the sand-resin mixture is in contact with the heated pattern and, after a predetermined time, the surplus sand mixture is allowed to fall away. The layer of sand is fully cured by transference of the pattern and adherent sand mixture into an oven. This curing produces a hard shell mould, accurately reproducing the original pattern, and the shell is stripped from the plate by means of ejector pins. The assembly of these shells into moulds can be achieved by clamping or gluing the shells together ready for casting.

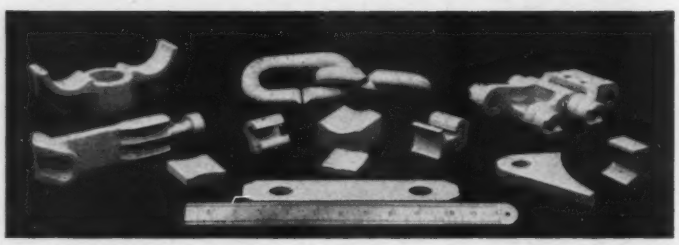
Cores to be used in conjunction with these shells can be produced by pouring or blowing a similar sand-resin mixture into a heated metal core box, and placing it in an oven long enough for curing to take place. In many cases hollow cores can be produced by pouring out the surplus sand after filling the core box. The better venting provided by a hollow core contributes to improved soundness and the ready collapsibility of a hollow core assists in the production of castings free from hot tearing.

The process has been adopted for the production of castings in a wide variety of metals and alloys and almost

* *Investment foundry manager, shell moulding department, Hadfields Ltd.*



Selection of castings for Caterpillar earth-moving equipment produced by the shell moulding process.



Group of castings in heat- and corrosion-resisting steels produced variously for the Superheater Co., Triplex Safety Glass Co., Priest Furnaces Ltd., Euart Chain Co. and Earles Cement Ltd.

TABLE I. Typical mechanical properties of shell moulded steels (obtained in a series of four tests)

Type of Steel		Heat Treatment	Yield Pt. t.s.i.	Max. Stress t.s.i.	Elong. %	R. of A. %	Izod ft. lb.
0·2% carbon steel	B.S.592, grade A	Annealed	14	28	22	—	—
	Sand cast		18	30·8	31	47	42–48
	Shell moulded		14·3–19·7	28·8–31·3	30–32	43–52	40–62
1·5% Mn steel	B.S.1456, grade A	Oil hardened and tempered	60% of M.S.	35–45	18	—	25
	Sand cast		28	40·4	25	48·4	34–35
	Shell moulded		29·5–33·8	41·6–44·8	21–26	34–54	35–52
1¼% Cr. Ni. Mo. steel	D.T.D. 666		45 (0·1% P.S.)	60	12	30	30
	Sand cast	Oil hardened and tempered	54	64·8	13	36·4	41–42
	Shell moulded		48·8–52·5	62·4–65·6	15–18	33·6–46	44–52
25% Cr., 12% Ni., 3% W. heat-resisting alloy	Sand cast	Normalised	17	39·2	23	22	—
	Shell moulded		15–15·8	36·7–38·2	31–34	31–36	32–41

Figures opposite B.S. and D.T.D. specifications are minimum properties required.

all materials used for castings have been advantageously cast into shell moulds.

High Accuracy

The application of this process to the making of steel castings has grown very rapidly in recent years. Castings varying in weight from a few ounces to 40 lb. are regularly being produced in quantity, often with appreciable advantage over normal sand foundry methods. In addition, the process is being used for making sections of moulds for castings of much larger proportions. Experience has shown that, by the adoption of the shell moulding process, a number of advantages can be gained over the production of similar castings by normal sand foundry methods. Due to the use of metal pattern equipment and the fact that the shell is stripped from the pattern plate in a rigid condition, a better standard of accuracy can be achieved, and the normal dimensional variations experienced from casting to casting are much reduced. Where the important dimensions can be produced in the same half of the mould, a very good standard indeed can be achieved, but, as with any two-piece mould, the accuracy is subject to some variation across the parting line. Claims have been made for dimensional accuracies of the order of ±0·005 in. for shell moulded castings, but such tolerances are most readily achieved in the lower melting point metals. So far as steel castings are concerned, a general accuracy of ±0·015 in. can be attained with an improvement on this in certain cases. Obviously the surface finish of a steel casting is not as good as that of lower melting point metals and this fact tends to limit the dimensional accuracy. The surface finish which can be achieved, however, on steel castings by the use of shell moulding is very much better than the finish of a sand casting. In the case of low-carbon steels, containing less than 0·25 per cent carbon, although sound castings can be produced, surface finishes are relatively poor. A comprehensive range of ferrous alloys is currently being cast. These include carbon, low alloy, manganese steel and a wide variety of corrosion- and heat-resisting alloys. The mechanical properties which can be achieved in shell moulded castings compare favourably with other castings and typical results on a variety of steels are quoted in Table 1.

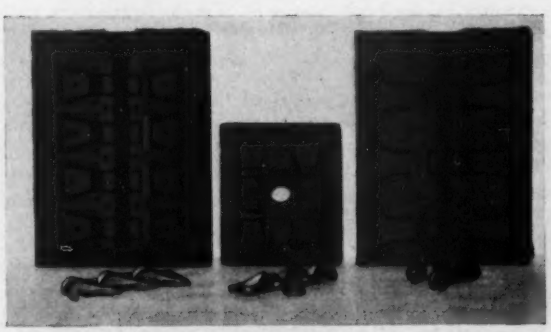
Many users are benefiting from the adoption of shell moulded castings. The higher accuracy of these castings will permit a reduction in machining allowances, this reflecting itself in lower machining costs, and the combination of accuracy and surface finish will in many cases allow the use of cast surfaces which previously were subject to machining. The surface finish achieved on shell moulded castings can undoubtedly enhance the appearance and saleability of equipment and machinery in which they are incorporated.

Designers might seriously consider, therefore, in what directions shell moulded castings can be of value to them. For instance, will the higher accuracy permit the use of cast surfaces where rough machining operations were previously essential? Will the use of shell moulded castings reduce generally the allowances to be made for machining and effect savings in cost and machine time? Will the improved surface finish enhance the appearance and attraction of the product they have to sell?

In designing for shell moulding, many of the considerations applicable to making sand castings should be borne in mind. For example, widely differing section thicknesses should be avoided as these can give rise to hot tearing and shrinkage defects overcome only by expensive feeding methods. Wherever possible, sharp corners should be avoided, particularly in re-entrant angles, and the maximum permissible radii should be employed, which in no circumstances should be less than $\frac{1}{32}$ in.

Suits Complicated Shapes

The avoidance of undercuts in the casting design will result in a cheaper casting and less-expensive pattern equipment. The shell moulding process is, however, suited to complicated shapes involving intricate coring and in this way ideal design features can be incorporated. The extra cost of a complex casting will in most cases be justified by



Shells used for manganese steel link castings.

Above. Placing hot shell in position to cure adhesive and stick shells together.

Above right. Pattern plate turning over on to dump box.

Right. Removal of cured shell from pattern plate.

the reduction in subsequent machining costs. Some of the accuracy which can be achieved has been previously expressed, but a valuable contribution can be made to the economics of a casting by the designer specifying close tolerances only where these are essential from a functional aspect or in avoiding machining.

Economics of Shell Moulding

Experience has shown that the price of shell moulded castings need not be higher than sand castings. Metal pattern equipment is essential and often substantial orders are required to justify its cost. The quantity of castings required depends a great deal on the value of the casting. In a simple casting the quantity which would justify the pattern cost might be many times that of a complicated casting where appreciable saving in machining would subsequently be achieved. Items of a repeat nature are well suited to shell moulding as the pattern equipment will produce many thousands of castings without significant wear.

It is not possible to generalise on the quantity required and each item must be considered on its own merits. Orders have been executed economically by shell moulding for as small a quantity as fifty of a complicated casting. On the other hand, repeat orders of tens of thousands at a time are currently being produced.

The accompanying illustrations will give some indication of the types of castings which are being successfully produced by this technique. Of particular interest is that showing a selection of castings for use in earth-moving equipment; by using shell moulded castings, interchangeability (where expendable parts are involved) has been achieved with a fraction of the dressing that would be required by sand foundry methods.

The higher accuracy of shell moulding has made it possible to produce highly alloyed castings requiring only grinding operations. A good example of this is the wide use of the process for magnet castings involving cobalt alloys of poor machineability.

In a matter of a few years shell moulding has become accepted as a versatile foundry method. Its increasing use should permit a higher standard of mechanisation in the handling of shells, cores and the pouring of castings. The resulting higher demands for raw materials may permit savings that will eventually be contributing to cheaper castings.

FOR FURTHER READING

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DESIGN ENGINEERING CONFERENCE

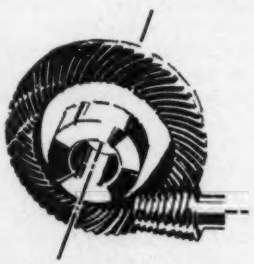
Highlights of some papers on design read at the A.S.M.E. conference in Philadelphia

LOGIC CIRCUITS FOR MACHINE CONTROL. *By Edgar V. Weir*

The term "logic" is used in control work to indicate the reasoning process through which the operation of one part of an automatic machine is co-ordinated with sequences of other operations. The flexibility of electrical controls compared with mechanical, pneumatic and hydraulic arrangements has resulted in their use for almost every automatic machine being produced today. The basic problems involved in the application of control systems to machines are discussed in this paper along with the basis of operation of three widely-used static control systems in which the magnetic amplifier plays a leading part. The reliability and trouble-free performance of static controls have been essential features in complex control systems. The possibility and limitations in the applications of relays and contactors are also discussed in detail.

THE DESIGN AND APPLICATION OF BELTS, CHAINS AND GEARS. *By E. S. Cheaney, C. L. Paullus and W. C. Raridan.*

This paper reviews the present state of the art of power transmission by the three basic types of mechanism, belts, chains and gears. Improved materials are continually extending the power range of belts, and special interest has been shown in the toothed belt because of its positive drive and high speed ratings. Chains are continually being developed for higher strength and longer life by using improved materials and heat treatments. Special applications to meet high-temperature or corrosive conditions are successfully achieved by using materials such as stainless steel. A recent innovation is the bead chain for relatively low speeds and power and allowing considerable shaft misalignment. Successful operation is claimed with shafts skewed at angles up to 90 deg.



A tapered worm gear —the link between hypoids and worm devices

Gear development is aimed principally at greater capacity for a given size, greater speed and improved reliability. A recent addition to the family of skewed-axis types is the tapered worm gear (see illustration) in which a tapered pinion permits engagement with mating teeth on the face of a bevel gear. This arrangement fills the gap between hypoids and worm devices.

VARIABLE-SPEED D.C. DRIVE SYSTEMS. *By Mark H. Sluis*

It is the intention of this paper to offer to the mechanical designer and engineer some assistance when confronted by the choice of three control schemes for attaining a variable-speed d.c. motor drive, such as for machine-tool feed or spindle drives.

The three most popular methods of d.c. motor control all use a means of controlled amplification. The variation of a small signal causes a proportional change of high-level d.c. output. These modes of amplification are categorised as rotary, magnetic and electronic. Discussion is limited to commercially available off-the-shelf equipment and does not report on prototype or laboratory performance. This presentation is made from a user's viewpoint having an unbiased choice and with the practicalities of his purposes and viewpoints uppermost in mind. There is no intention to promote any particular scheme or device, but merely to pass along some generalised information to aid selection.

DESIGN CURVES FOR JOURNAL BEARINGS. *By Donald F. Hays*

In the design of journal bearings, it is important to know of the relationships between the operational geometry of the bearing and such parameters as load, speed, viscosity, length/diameter ratio and clearance ratio. These relationships have been difficult to ascertain because of the difficulties in obtaining a solution to Reynolds' equation for the finite bearing. Either the assumption of an infinitely long bearing was accepted, or a bearing which was extremely narrow was postulated and the results obtained were used with considerable reservation when outside of the limited range of L/D ratios. There is now a technique whereby the finite bearings can be analysed for all of its characteristics.

A series of design curves is presented to illustrate the variation of minimum film height with load variable and the variations of the coefficient of friction with the Sommerfield number. The film is assumed to be continuous and the fluid to be incompressible. A series of illustrative examples is worked with the curves.

WHICH BEARING AND WHY? *By A. O. De Hart*

The machine designer is faced by a formidable and seemingly endless array of bearing types from which to make a selection. In order to help the designer in this dilemma, a survey of the pertinent selection factors is given in this paper. Bearing types—fluid film and rolling contact —are covered as well as application data. Emphasis is given to bearing types—externally pressurised with restrictor control and self-pressurised—which show promise in machine-tool applications.

SEMICONDUCTOR POWER-CONVERSION EQUIPMENT. *By J. J. Rheinhold*

A source of dependable d.c. power has become an essential requirement for efficient operation of to-day's manufacturing plants, whether this is for the drive and control of automatic machinery or for use in the large power-consuming electrochemical process plants. The semiconductor conversion method offers a convenient, economical and efficient means to supply this demand over a wide range of application. Even applications of very large power requirements which were previously served exclusively by rotating machines or mercury-vapour rectifiers are now being supplied by the newer semiconductor devices. This paper compares the characteristics of the present-day semiconductor devices, copper oxide, selenium, germanium and silicon rectifiers and their optimum applications.

EFFECT OF MOLYBDENUM SPRAYING ON ADHESION OF METALS

by D. BIRCHON, B.Sc., A.I.M., A.I.Mar.E.*

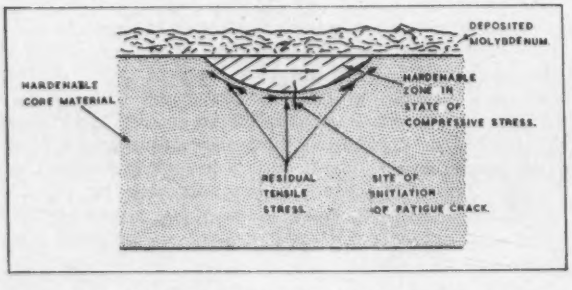
METAL spraying has long been established as a valuable technique for the deposition of protective coatings and for the reclamation of worn components of machinery. The adhesion between the sprayed and basis material is usually obtained by a purely mechanical interlocking action, which necessitates the production of a suitably roughened surface upon the basis material. Cylindrical components may be rough threaded, and plane and irregular surfaces may be shot-blasted to establish the necessary surface topography.

In recent years it has been shown that molybdenum will adhere to fine machined and even ground surfaces of steel without relying upon a mechanical key, and the roughened surface of the molybdenum then provides an excellent condition for the reception of a subsequent deposit of other material. The abrasion resistance of deposited molybdenum is very good and a thin layer is often used alone for the protection of rollers and guides used in textile and similar machinery; in such applications it has been shown to greatly enhance the life of the component and also to provide an excellent reclamation technique.

The possibility that a thin molybdenum underlay could be used upon a fine machined surface to provide adhesion without resorting to rough threading or grooving was immediately recognised, but experience has shown that the deposition of molybdenum upon a fine machined surface may reduce the endurance limit of the component. This somewhat surprising effect has been reported and investigated by a number of observers and it has recently been shown that it is principally due to a combination of two phenomena.

The high melting point of molybdenum (2,620 deg. C.) is such that the impact of the hot particles upon the surface of a ferritic steel raises the temperature of tiny local zones above the change points. These zones are then effectively quenched by the relatively large heat sink provided by the remainder of the component, with the result that they are hardened. The time for which the high temperature is maintained is insufficient to permit homogenisation of the austenite, but a hard quasi-martensitic structure is produced. This partial transformation is accompanied by a volumetric expansion which introduces an intense local residual stress system just beneath the surface as shown in Fig. 1.

The high compressive yield strength of the tiny hardened zones prevents effective stress relaxation when the applied stress is compressive, and the residual tensile stress beneath the hardened zone is additive to the cycles of tensile service stress. Thus, at service stresses below the endurance limit of the material, the residual tensile stress assists the initiation of a fatigue crack just beneath the surface, across the boundary of the hardened zone. This crack may then propagate across the section.


DEPOSITED MOLYBDENUM
HARDENABLE CORE MATERIAL
HARDENABLE ZONE IN STATE OF COMPRESSIVE STRESS.
RESIDUAL TENSILE STRESS.
SITE OF INITIATION OF FATIGUE CRACK.

Residual stress pattern in a typical hardened zone.

The amount by which the fatigue resistance is reduced is closely related to the ultimate tensile strength of the material. The reduction observed in the endurance limit of 0·350-in.-diameter specimens tested in rotating bending has been shown to vary from 20 per cent for a steel of 32 t.s.i. U.T.S. to 61 per cent for a heat-treated alloy steel of 78 t.s.i. U.T.S.

Consideration of the reasons for this reduction in endurance limit indicates that there are several ways in which the benefits of molybdenum spraying may be secured without serious degradation in the endurance properties of the component. If an austenitic steel is used for the basis metal, the freedom from phase changes greatly reduces the effect of the molybdenum, but the cost and low elastic limit of stable austenitic steels severely restrict their use for structural applications. If a ferritic or quenched and tempered steel is necessary for the core material, a reduction in the severity of quenching afforded by the bulk of the component may be obtained by maintaining a low level of preheat during spraying. The level of this preheat must be restricted, since a thick oxide film would seriously reduce the adhesion produced by the molybdenum. This technique is of limited value and it has not been fully investigated.

It has been shown, however, that the combination of a suitable shot-blasting procedure with a thin underlay of molybdenum provides adhesion comparable with that provided by conventional rough threading without the use of molybdenum, and fatigue properties equal to those of the base material in the polished condition. These results were obtained upon 0·350-in.-diameter specimens tested in rotating bending and it is therefore necessary to interpret the figures with caution, since in larger components the distribution of service stresses will affect the overall performance.

It is probable that a similar reduction will occur whenever a metal of high melting point is deposited in a near-molten condition upon a hardenable steel base, and care must therefore be exercised in the application of other high melting point materials such as tungsten, tungsten carbide, etc. In the absence of high fluctuating stresses, the only danger attendant upon the presence of these tiny hardened zones would be the possibility that they could assist the initiation of a crack under impulsive loading. Consideration of this aspect must depend upon the individual case.

It should be noted that in terms of the number and diversity of components which are successfully sprayed with molybdenum and similar materials, the proportion of fatigue failures has been very small. Provided that due consideration is given to all the factors involved, the valuable potentialities of surfacing methods, involving the deposition of high melting point materials by spraying, may be employed with confidence.

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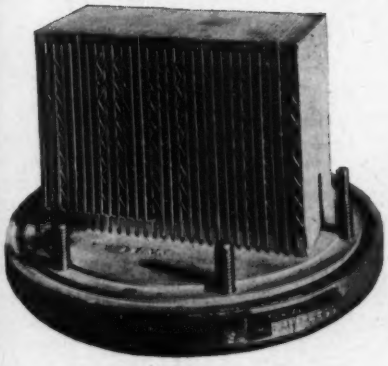

Light alloy magnetron valve cooler by Marston Excelsior (half lifesize).

COMMON FACTORS IN THE DESIGN OF HEAT EXCHANGERS

The transfer of heat from one fluid to another is a requirement in almost every field of modern industry. This article explains some of the important factors to be observed in designing heat exchange units

by A. J. EDE*

THE function of a heat exchanger is the transference of heat from one fluid to another. This operation is an essential feature of a great variety of activities in industry and everyday life, and heat exchangers correspondingly take on an almost limitless variety of forms—from the radiator of the motor car to the condenser of a steam turbine and from the water heater over the kitchen sink to the giant heat exchanger of a nuclear power station. With a few exceptions, however, which will not be considered here, they are basically similar: they all provide channels through which the fluids are conveyed so that they are brought into intimate thermal contact with one another, while remaining physically separated by a partition. The variety lies in the shape and size of these channels, and other features, such as baffles and fins, provide further opportunities for variation. Certain convenient forms, including, for example, the shell-and-tube, emerged at an early stage in the history of the heat exchanger and are still very widely used today, but in recent years new problems, new materials, new manufacturing techniques and a growing knowledge of the basic principles of heat transfer have led to the introduction of designs departing very far from the traditional.

Selecting a heat exchanger for a given duty involves choosing the type and calculating the size. Since completely new applications are seldom encountered, the industrial designer usually has a store of past experience on which to draw and the appropriate heat exchanger can often be selected merely by consulting a table. For anything at all unusual, however, he has to fall back upon certain general principles underlying the selection of one type of exchanger rather than another, the available information on the basic processes of convection, and the techniques for applying this information to the more complicated processes which occur in an actual exchanger. A brief account of these methods and principles should be of interest to the considerable body of engineers who are actively concerned in the use of heat exchangers but seldom have to undertake the design of a new exchanger.

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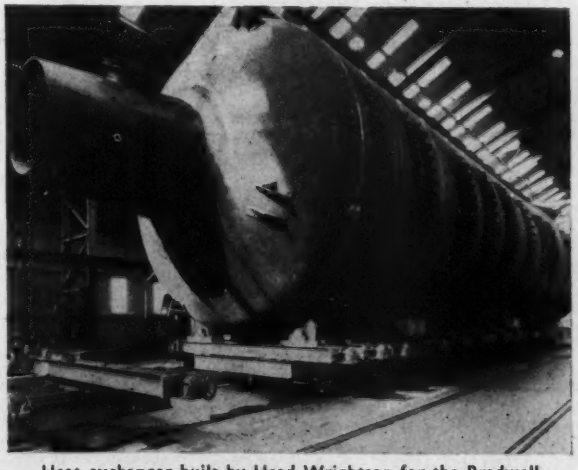
The overall performance of a heat exchanger may be defined by stating the two fluids, their rates of flow and their inlet and outlet temperatures. If the two rates of flow and the two inlet temperatures are given, the maximum heat transfer which can theoretically be obtained is that corresponding to the heating of the colder fluid to the inlet temperature of the hotter fluid, or the cooling of the hotter fluid to the inlet temperature of the colder fluid, whichever is the less. This performance would be obtained in a simple countercurrent heat exchanger of infinite size and represents a datum against which the performance of any actual exchanger may be assessed. Provided the required duty lies within this limit, it is possible to design a heat exchanger to achieve it. However, there are many other aspects which must be considered, including the pressure differences needed to force the fluids through the exchanger, and in practice the designer may approach the problem from many different



Heat exchanger built by Head Wrightson for the Bradwell nuclear power station.

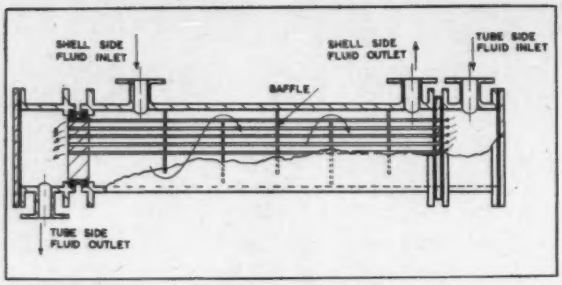


Fig. 1. Shell and tube heat exchanger.

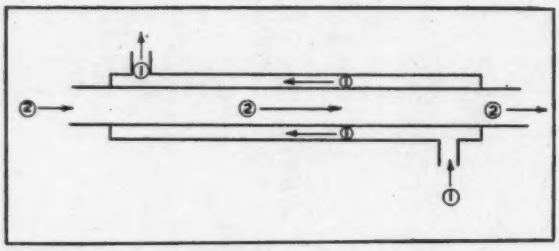


Fig. 2. Simple counter-current heat exchanger.

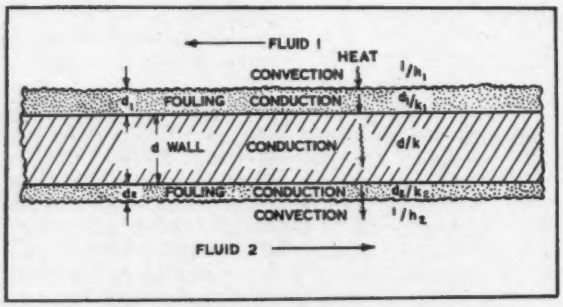


Fig. 3. Basic processes in transfer of heat from one fluid to another through a solid partition, showing components of the overall resistance to heat transfer. (d—thickness; k—thermal conductivity; h—heat-transfer coefficient.)

angles, depending on his basic assumptions and the relative importance of the various considerations involved. It is impossible to examine all conceivable cases individually, and this survey must be limited to noting some of the more important general factors the designer is likely to have to take into account, over and above the basic heat-transfer requirements. These are:

1. The cost of the heat exchanger and any associated equipment and the cost of replacing worn-out components, including the cost of holding up production while such replacements are made.
2. The feasibility and cost of keeping the heat exchanger sufficiently clean to maintain an adequate performance.
3. The feasibility and cost of maintaining the requisite rates of flow, including the suitability of the pressure drops involved and the cost of any additional pumping, etc., required.
4. The suitability of the heat exchanger from a structural standpoint, i.e., its ability to withstand the pressures, temperature stresses and so on to which it will be subjected.
5. The weight, size, shape, etc., of the heat exchanger; there may be special requirements or limitations.
6. The suitability of the materials of construction for resisting corrosion and erosion.

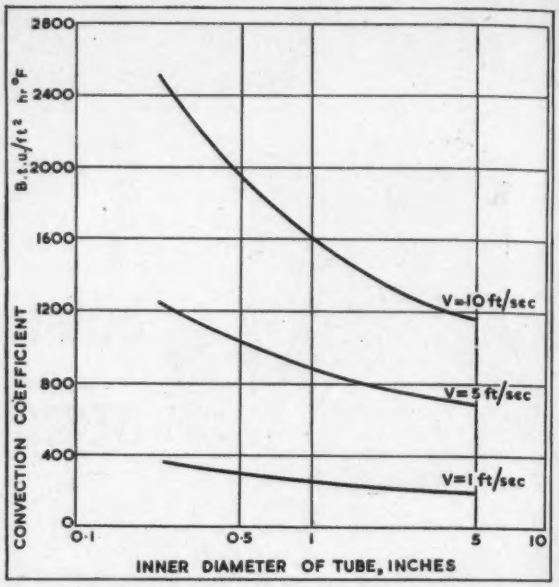


Fig. 4. Typical simplified graph for determining heat-transfer coefficients at 60 deg. F. at different velocities.

The relative importance of these factors will vary from case to case and they may well turn out to be in conflict. Thus the attempt to achieve compactness may result in the pressures drops involved being too severe; a highly efficient exchanger from a purely thermal standpoint may turn out to be too costly, or difficult to clean.

In selecting the type of exchanger the best guide is past experience, since only actual operation can reveal the unexpected advantages or drawbacks of a particular design when used for a particular purpose. There are, however, a number of principles which are sufficiently general to be worth mentioning. For example, higher speeds tend to reduce fouling and increase heat transfer, but put up pressure drop and may cause erosion. Another is that turbulence promoters and other devices for disturbing the flow give high heat-transfer rates, usually, however, at the expense of large pressure drops. Third, laminar flow gives a high ratio of heat transfer to pressure drop, but heat-transfer coefficients are small and the exchanger becomes large.

In the case of the very common shell-and-tube heat exchanger and similar types, it is necessary to decide which fluid is to be passed through the tubes and which through the shell.

1. It is easier to clean inside the tubes than outside; therefore, if one of the fluids is more likely to cause fouling than the other it should be passed through the tubes.
2. If one of the fluids is at a high pressure, it is simpler constructionally to pass it through the tubes.
3. If one of the fluids has a very small permissible pressure drop, or is very viscous, it is usually better to pass it through the shell side.
4. Heat losses may be minimised by passing through the shell side the fluid whose temperature lies nearer to the ambient.

On the basis of considerations such as these, a tentative decision can be made about the nature of the proposed heat exchanger. The next step is to hazard a guess at some of the variables involved and work out the design in detail; the performance, size, cost, etc., can then be compared with the requirements of the case. The experienced designer will usually have tabulated data avail-

able to him which will greatly facilitate this task. It will be assumed here, however, that the exchanger is to be designed from basic data. It must be admitted at once that since the flow of the fluids and the transfer of heat in even the simplest exchanger are complex processes, the calculation of performance involves a series of drastic approximations, and in some cases the results can be regarded as very rough estimates only.

All the heat transferred in an exchanger passes through the partition separating the two fluids. This process can be broken up into three steps: the transfer of heat from the hot fluid to the surface of the partition by convection, through the partition itself by conduction, and from the other surface to the colder fluid by convection. With certain qualifications, the rates at which heat flows by these processes are proportional to the respective temperature differences. For the partition, the rate of flow of heat through unit area equals the temperature difference between the two surfaces multiplied by k/d, where k is the thermal conductivity of the material of which the partition is made and d the thickness. For each of the two convective processes, the heat flow equals the temperature difference between the fluid and the surface of the partition on that side, multiplied by the appropriate heat-transfer coefficient. The value of this coefficient depends chiefly on the properties of the fluid and its velocity, and is normally independent of the nature of the solid partition. It may be found by consulting the standard works on heat transfer (see bibliography at end of this article) where data are provided for a wide range of possible situations, including, for instance, flow inside and outside tubes, boiling and condensation. The presentation of such data usually involves the use of dimensionless groups, which have been introduced as a means of simplifying and condensing the vast amount of information which would be required if data were to be presented specially for every velocity, tube diameter and so on. As an example, data on heat transfer in pipe flow may be given as an equation such as the following:

$$\frac{hD}{k} = 0{\cdot}023 \left(\frac{V\rho D}{\eta}\right)^{0{\cdot}8} \left(\frac{c\eta}{k}\right)^{0{\cdot}4}$$

where h is the required heat-transfer coefficient, D the diameter of the pipe, V the velocity of the fluid and k, ρ, η and c respectively its thermal conductivity, density, viscosity and specific heat. The three groups occurring in this equation are commonly known as the Nusselt, Reynolds and Prandtl numbers respectively, and there are several others of a similar nature which frequently occur. For certain special cases simplified formulæ and graphs have been published; many designers, faced with a succession of calculations of a similar type, prepare their own graphs and tables.

Having determined the two convective coefficients and the corresponding factor for the partition itself, the next step is to calculate the overall heat-transfer coefficient—that is, the heat transferred in unit time from one fluid to the other through unit area of the partition wall, for unit overall temperature difference. The partial coefficients so far considered are effectively conductances, so that their reciprocals are resistances and may be added, since they occur in series in the path of the flow of heat. The reciprocal of the sum is the required overall coefficient.

This is a convenient point for taking account of any fouling which is likely to develop on either or both of the surfaces of the partition; the heat exchanger must still be able to function satisfactorily when it is at its dirtiest, that is, just before it is due for cleaning. If the nature of the fouling can be reliably foreseen, its effect can be included in the calculation by treating it as an additional layer or layers of material on the partition, each contributing its own $\frac{d}{k}$ to the total resistance to the flow of heat, so that the overall heat-transfer coefficient, U, is found from the equation:

$$\frac{1}{U} = \frac{1}{h_1} + \frac{d_1}{k_1} + \frac{d}{k} + \frac{d_2}{k_2} + \frac{1}{h_2}$$

where suffixes 1 and 2 refer to the two fluids and their corresponding layers of fouling.

(This equation is based on the assumption that the partition is flat; in most cases it is curved, so that corresponding areas on the inner and outer surfaces differ, and the equation must be modified accordingly.)

Usually, however, neither the thicknesses nor the thermal conductivities of fouling layers are known with any precision, and in place of $(d_1/k_1 + d_2/k_2)$ designers often include a "fouling factor" which has been determined from past experience under similar operational conditions.

The relative magnitudes of the five components of the overall coefficient are worthy of careful consideration. If, for instance, the coefficients h_1 and h_2 are comparatively small, as in a gas-to-gas heat exchanger, $\frac{1}{h_1}$ and $\frac{1}{h_2}$ will be

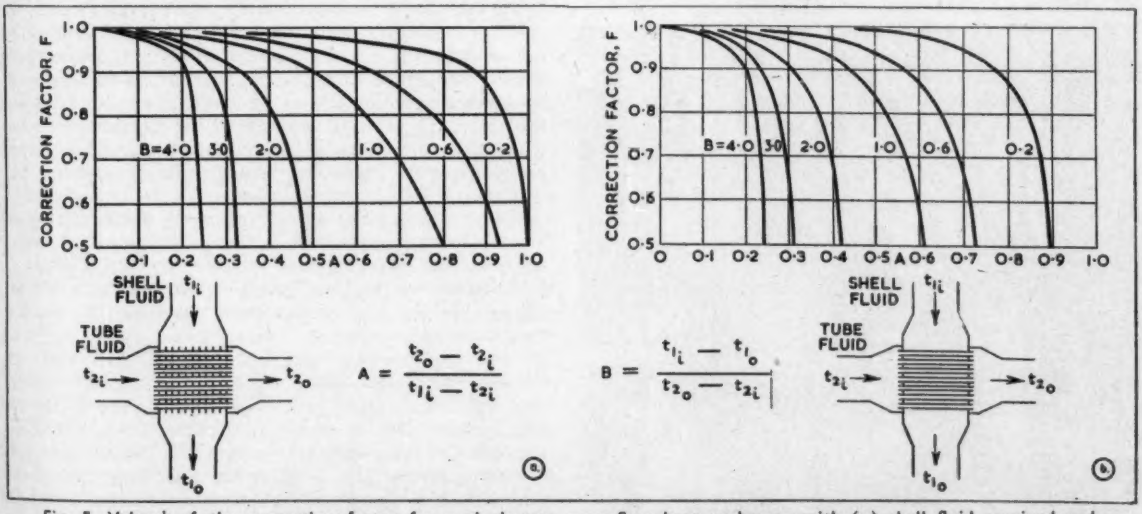
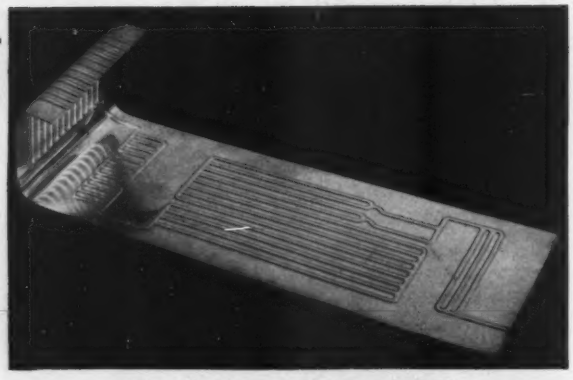


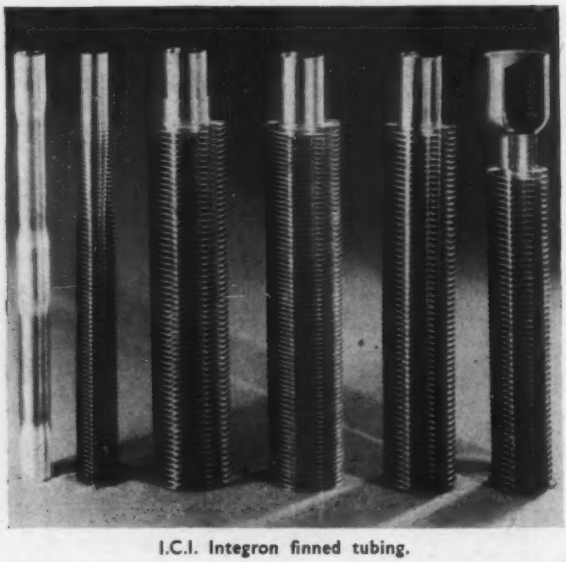
Fig. 5. Values[1] of the correction factor for a single-pass cross-flow heat exchanger with (a) shell fluid unmixed and (b) shell fluid mixed. Unmixed flow of the shell fluid is secured by provision of longitudinal baffles in cross-flow exchangers. The tube fluid may be regarded as unmixed. Correction factors for multi-pass heat exchangers and for other complicated systems are given elsewhere.[2]

large and the contribution of the $\frac{d}{k}$ of the partition may well be negligible. Again, if the fouling factor is large, attempts to improve heat transfer by increasing h_1 or h_2 may have little effect. In general, the most effective way of improving performance is to tackle the largest of the resistances. In a good heat exchanger the partition and fouling resistances will be low and the two convection coefficients, h_1 and h_2, will be of the same order of magnitude. The simplest way of achieving a balance between the two is by manipulating the fluid velocities; this can be achieved in a variety of ways; for example, in a shell-and-tube heat exchanger the velocity through the tubes can be increased by making them of smaller diameter, or fitting blanked-off "cores"; and the velocity on the shell side can be increased by inserting baffles to compel the fluid to follow a tortuous path.

Sometimes the two coefficients are naturally very different; for example, when heating air by a steam-heated battery, the steam-side coefficient may be 100 times greater than the air coefficient. An improvement can then be effected by adding fins, etc., to the side having a low heat-transfer coefficient, thereby extending the surface area. By this means the concentrated flow of heat on the side having a high coefficient is spread out by conduction over the much larger surface of the fins so that it matches the lower heat-transfer coefficient. If the heat-transfer coefficients are respectively h_1 and h_2 and the total surface area on the finned side is c times that on the unfinned side, the resistances corresponding to unit area on the unfinned side will be $1/h_1$ and $1/ch_2$, so that by a suitable choice of c the balance between the two may be restored. This is an oversimplification; in practice, even with very carefully designed fins, not all the additional surface provided is equally effective and a "fin efficiency" factor is used to correct the result.



Roll welded heat-transfer sheet by I.C.I.



I.C.I. Integron finned tubing.

There are many other points which have to be settled, tentatively at least, before the final calculations can be embarked upon. For example, in a shell-and-tube exchanger the fluid in the tubes may be made to pass a number of times through the exchanger, back and forth; on the shell side the same effect can be achieved by means of baffles. The arrangement and pitch of the tubes forming the bank must be chosen. The number of possible variations is unlimited, and there are other types of exchanger beside the shell-and-tube. Some degree of standardisation has, however, emerged, and the properties of certain specific types are discussed in the literature. In making a choice, constructional feasibility and ease of cleaning are factors to be considered, and the rates of flow and temperature ranges of the two fluids are also important.

Reverting to the calculation of the overall heat transfer, and assuming that U has been determined, the local rate of heat transfer may be found by multiplying U by the local overall temperature difference. Since both of these usually vary with position in the exchanger, calculation of the total heat transfer involves integration, and this procedure is in fact followed in some cases. More often, however, the variation of U is small and an average value may be accepted as sufficiently representative of conditions throughout the exchanger. Complete simplification of the calculation requires the use of an average temperature difference also; this is more difficult as the local value usually varies considerably, so that serious error can be caused by an incorrect choice.

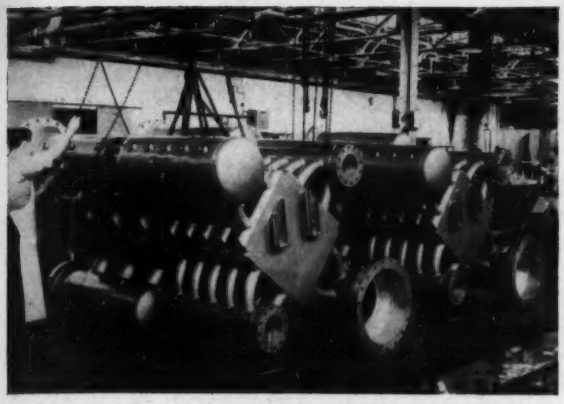
For certain basic types of heat exchanger, including the simple countercurrent type, it may be shown that if the overall temperature differences at the two ends of the exchanger are $\triangle\theta_1$ and $\triangle\theta_2$, the total heat flow corresponds to that which would be obtained if the temperature difference were everywhere equal to

$$\frac{\triangle\theta_1 - \triangle\theta_2}{\log_e \triangle\theta_1 - \log_e \triangle\theta_2}$$

the so-called logarithmic mean temperature difference. Unfortunately, few practical heat exchangers conform precisely even to this relation, and in fact most exhibit significant departures from it. By complicated analysis or by experiment, the characteristics of a considerable number of common types have been determined and are available in the literature. They are given as correction factors which must be applied to the logarithmic mean temperature difference, and are usually presented as graphs which require a knowledge of both inlet and outlet temperatures before they may be used.

The necessary data for calculating the performance of the heat exchanger have now been assembled. It is assumed that the two inlet temperatures and flow rates have been fixed and a suitable value calculated for the overall heat-transfer coefficient. If the object is to find how large the exchanger must be to achieve a given thermal performance, the outlet temperatures and the corresponding total heat transfer will also have been specified. The logarithmic mean temperature difference can, therefore, be calculated and the correction found for the type of heat exchanger proposed. The surface area needed is obtained by dividing the total heat transfer by the product of the overall heat-transfer coefficient and the corrected logarithmic mean temperature difference.

If, on the other hand, the surface area is specified and it is desired to calculate the performance, a trial-and-error



Pair of Marston Excelsior industrial light-alloy heat exchangers.

method must be adopted, since the logarithmic mean temperature difference cannot be found until the outlet temperatures are known. A preliminary guess at the total heat transfer is made and the corresponding outlet temperatures calculated. The logarithmic mean temperature difference is deduced, corrected if necessary, and used to calculate the overall heat transfer. This result is compared with the original guess. In general it will not agree and the process must be repeated until eventually guess and calculated value coincide. There are, of course, many variants on the problem, since the initial data may take many forms, but in essence they may all be treated in the same way.

In some cases a simplification is provided by a method developed by Kays and London. This introduces some new concepts:

1. The "capacity rate" of each fluid, C, i.e., the mass rate of flow multiplied by the specific heat.
2. The number of transfer units, NTU, i.e., the product of the overall heat-transfer coefficient and the total effective area divided by the smaller of the two capacity rates.
3. The "effectiveness", ξ, the ratio of the total heat transfer to the maximum theoretically obtainable in a countercurrent heat exchanger of infinite area (see above) having the same inlet temperature and flow conditions.

The effectiveness involves the two inlet temperatures and one outlet temperature, and in a problem such as has just been considered only the entry temperatures are known. A simple analysis shows, however, that the effectiveness can be expressed as a function of the number of transfer units, the ratio of the two capacity rates, and the logarithmic mean temperature difference correction factor appropriate to the heat exchanger under consideration. For any particular type of exchanger, therefore, the effectiveness can be plotted against the number of transfer units for a series of values of the ratio of the capacity rates. In a typical problem the number of transfer units and the ratio of the capacity rates can be calculated at once from the given data, so that the effectiveness can be determined directly from the appropriate graph; as this involves three temperatures, two of which are already known, the problem is immediately solved and no trial-and-error procedure is necessary.

The calculations are still not finished, since in most cases it is equally important to determine the pressure differences required to produce the specified rates of flow; the two fluids are, of course, dealt with separately. The basic data needed will be found in the same general works on heat transfer; in many instances dimensionless groups are used for presenting the information. It will also be necessary to consider the structural design of the exchanger, the materials to be used and so on.

The designer will now have built up on paper a complete heat exchanger and he will have to consider its merits and demerits from the various points of view noted above: thermal performance, capital cost, running cost, etc. Usually it will turn out to be unsatisfactory in some respect and a fresh attempt must be made. In most cases the final solution will be a compromise, and if the best that can be done is still unsatisfactory it will be necessary to alter the original requirements or consider a different type of exchanger.

It is probably true to say that the design of a heat exchanger is still to a considerable extent an art rather than a science, although the proportion of science is continually increasing as the flow of fresh data from the many centres of research and development is disseminated. In the past, the designer has been able to offset the lack of precision in his work by making heat exchangers larger by a considerable margin than his calculations would suggest; in this way he has played for safety, ensuring that an exchanger at least did the job for which it was designed, even though it might cost more to make or operate than was strictly necessary. Nowadays something rather better than this is expected; and in many modern applications the success or failure of the whole project may depend on the ability of the designer to meet a very tight specification indeed. It is to equip him for meeting these specifications, and for producing strictly economical designs generally, that research units such as the heat division of the National Engineering Laboratory are devoting their efforts, and in conclusion certain aspects of this work will be briefly mentioned. In the first place, existing basic data on heat transfer tend inevitably to be primarily concerned with the simple idealized cases—the long straight pipe, for example. These are undoubtedly the most important cases, but they do not tell the whole story and the next step is to obtain more information about the corrections necessary when, as may well occur in practice, considerations such as end-effects are significant. Second, some of the newer types of heat exchanger present such complicated problems in heat and fluid flow that direct experiment is at present the only practical way of determining performance. Third, even when the heat exchanger is simple in design and construction, divergences between actual and predicted performance may be encountered and efforts are being made to determine the reason for these differences. Fourth, some of the fluids now being used, including liquid metals, non-Newtonian liquids, fluidised solids and slurries, differ so much from fluids such as water and air that data obtained with these more "normal" substances are not applicable, and special investigations are required. In these and other fields the research worker is endeavouring to provide the information that the designer needs now or is likely to need tomorrow.

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1. Fig. 5 is reproduced by permission from *Technical Data on Fuel*, 5th Ed., 3rd Imp., Brit. Nat. Comm. World Power Conference.
2. R. A. Bowman, A. C. Mueller and W. M. Nagle, *Trans. A.S.M.E.*, 1940, **62**, 283.

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NEW HIGH-TEMPERATURE MATERIALS

Two special ceramic materials that have received attention recently here and abroad are silicon nitride and boron nitride. Their value in many high-temperature applications is discussed in this article

THERE is a constant search for new or improved materials for use at high temperatures, and when new equipment is designed the engineer is often faced with the question: "What is the best material for this particular job?" This cannot be answered unless the designer understands the behaviour of the materials available, such as the temperatures the materials will stand in a given atmosphere, resistance to corrosion, and their dielectric properties.

A symposium held by the British Ceramic Research Association last July dealt exclusively with that group of new non-metallic, inorganic materials known as special ceramics, with particular emphasis on non-oxide ceramics.*

Two little-known ceramic materials which have been studied recently both in this country and in the U.S.A. are boron nitride and silicon nitride. These are both excellent electrical insulators which withstand high temperatures; they can be used at 1,700 deg. C. or above in a nitrogen atmosphere.

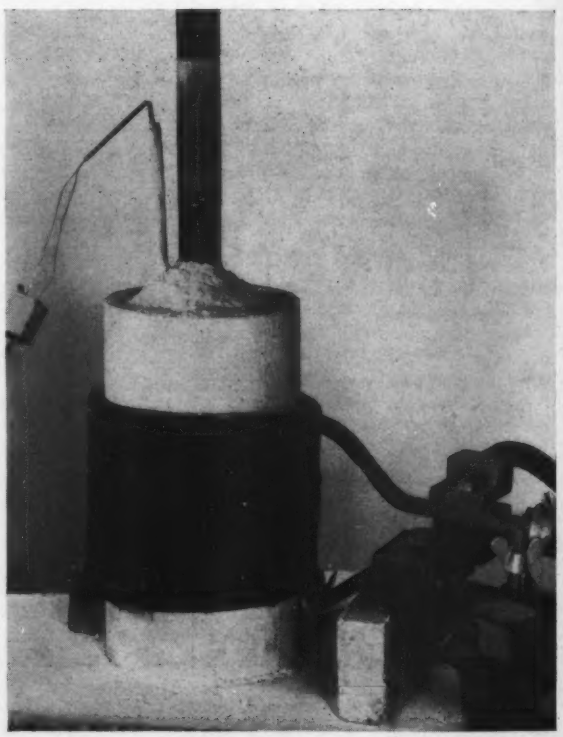
Silicon Nitride

Silicon nitride is a strong, hard material which will withstand high temperatures and has a high resistance to thermal shock and to attack by many chemicals and molten metals.

It can be made in any shapes which can be slip-cast, pressed or extruded, since silicon powder, mixed with the appropriate binders, can be treated in any of these three ways and then nitrided by firing at about 1,350 deg. C. in oxygen-free nitrogen. The time required depends on the size of the article and the temperature. The bodies so formed, though still porous, are very strong. Discs of 1½ in. diameter, bars 3 in. long, crucibles of $\frac{1}{16}$ in. wall thickness and rocket inserts of 2¼ in. outside diameter have been formed satisfactorily at the British Ceramic Research Association.

One of the most attractive features of silicon nitride is that only a small dimensional change generally may be expected to occur during firing: consequently, excellent dimensional tolerances can be maintained. Similarly, there is no tendency to sag during firing: it is reported that silicon nitride thermocouple tubes have been consistently cast with a centre-line tolerance of ±0·01 in. per ft. There is very little deformation during nitridation and excellent dimensional tolerances can be maintained; pressed articles show about 1 per cent linear expansion.

Silicon nitride bodies are reported to be harder than similar alumina or silicon carbide bodies, and silicon nitride thermocouple protection tubes to have a longer life than alumina ones, owing to their higher resistance to thermal shock. The strength of silicon nitride bars is intermediate between those of alumina and commercially available silicon carbide. The thermal expansion is low.



Assembly for hot-pressing boron nitride by induction heating.

It is also a good electrical insulator at both room and elevated temperatures.

The surface of the article sometimes becomes covered with an impervious glaze (possibly silica) during the nitridation. The density and strength depend on the density of the silicon body before nitridation and this will depend on the precise conditions of forming. Densities of 2·0-2·6 g/cc, corresponding to porosities of 37-18 per cent, have been obtained from pressed bodies at the B.Ceram.R.A. The results given below refer to bodies of total porosity of the order of 25 per cent.

Mechanical Properties	
Modulus of rupture	16,000-20,000 p.s.i.
Compressive strength	72,000-90,000 p.s.i.†
Mohs hardness	9†
Rockwell hardness	99†
Diamond-pyramid hardness (on single grains)	2,400-4,300†

THERMAL PROPERTIES

Temperature of sublimation ...	1,900°C.†
Thermal expansion (20-1,000°C.)	$2{\cdot}5 \times 10^{-6}$/°C.
Thermal conductivity	0·0037 c.g.s.†
Thermal shock resistance	Very good

ELECTRICAL PROPERTIES—Because of its porosity, the resistivity and dielectric loss at room temperature depend on the humidity of the ambient atmosphere.

Resistivity at 20°C.	$1{\cdot}6 \times 10^{10}$ ohm cm
„ „ 20°C. (after drying)	10^{13} „ „
„ „ 400°C.	10^{11} „ „
„ „ 700°C.	10^{8} „ „
„ „ 1,050°C.	10^{6} „ „
Dielectric constant	9·4
Dielectric loss tangent, at 1 Mc/s	0·001-0·01

Large values of dielectric constant and loss tangent are found if the silicon has been incompletely nitrided.

CHEMICAL PROPERTIES—Two phases (α and β) frequently co-exist, and their composition corresponds to Si_3N_4.

Oxidation Resistance. Silicon nitride has a high resistance to oxidation at temperatures up to 1,200 deg. C. Silicon nitride articles held at 1,000 deg. C. in air for 100 hours showed weight gains of 6-14 mg./sq. cm., depending on porosity. A specimen treated at 1,200 deg. C. showed a weight gain of 5 mg./sq. cm. during the first two hours, but no further gain during a further 80 hours heating.† This is probably due to the formation of an oxide coating on the article, preventing further oxidation. At 1,400 deg. C. oxidation proceeds rapidly.

Resistance to Acids and Bases. Silicon nitride shows a good chemical stability, being resistant to the attack of most acids. It is slowly attacked by hydrofluoric acid and by solutions of caustic soda stronger than 25 per cent.

Resistance to Molten Metals and Glasses. Silicon nitride is highly resistant to attack by non-ferrous metals and most glasses. In fact, it is not even wetted by many of them.

APPLICATIONS—The following applications have been suggested; they are based on the high resistance of silicon nitride to attack by molten metals, acids, etc., its good thermal shock resistance, high electrical resistivity and the possibility of manufacture to good dimensional tolerances.

1. As thermocouple sheath for use with molten aluminium.
2. For aspirator thermocouple assemblies used to measure the temperature of combustion gases in furnaces.
3. As a mould wash.
4. For crucibles to hold molten metals.
5. As electrical insulators.
6. As turbine and rocket components.
7. As jigs in transistor production.
8. As components in chemical plant.
9. High temperature bearings.
10. Components in nuclear reactors.

Boron Nitride

Boron nitride is a white material with the appearance of talc. It is an electrical insulator that can be easily machined, withstands high temperatures in oxygen-free atmospheres and resists attack by molten glass, aluminium and silicon. It crystallises in thin flakes and the well-crystallised powder with a very low packing density can be used as a thermal insulation material. Boron nitride is soft, like graphite, with a low coefficient of friction, which makes it a potential solid lubricant.

Crucibles for melting silicon have been made by cold-pressing the powder and firing this in nitrogen, but where higher strength is required hot-pressing must be used. The machineability of hot-pressed boron nitride allows the manufacture of articles of complicated shape. As a refractory, machineable, electrical insulator, it has been found suitable for making spacers for use in high-temperature furnaces.

Hot-pressed boron nitride normally contains some boric oxide and/or other additions, which are essential if the article is to have a low porosity and high strength. Since boric oxide is soluble in water, it reduces the stability of the hot-pressed article in water and steam. Certain additives offset this effect by converting the boric oxide into an insoluble borate.

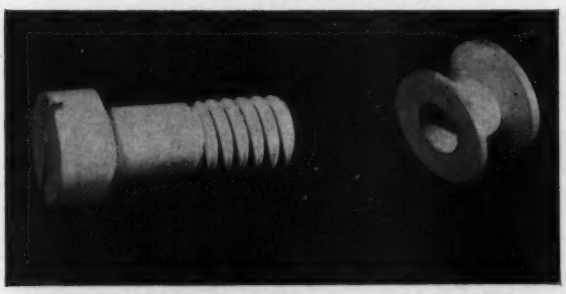
The presence of some additives makes the material harder though it is still easily machined. Their amount can be varied to give the material different properties, e.g., greater mechanical strength or higher chemical stability. When considering the suitability of boron nitride for a particular application, it is important that the application should be known to the manufacturer. Only in this way can material of the most appropriate composition and fabrication process be supplied and the trials be considered satisfactory.

Powder prepared at 900 deg. C. is easily hot-pressed at 1,600-1,800 deg. C. and 500-2,000 p.s.i. to a density of 2·10 g/cc, but the product contains a considerable amount of boric oxide. The purity of hot-pressed boron nitride can be improved either by treating the powder in nitrogen or vacuum at a higher temperature. Very pure boron nitride is difficult to hot-press.

The properties of boron nitride depend on its porosity and purity. The properties quoted are a collection of both published data and data obtained by the B.Ceram.R.A., the N.P.L. and the National Engineering Laboratory on B.Ceram.R.A. material and on material supplied by the Carborundum Co., U.S.A.

MECHANICAL PROPERTIES—The kinetic friction coefficient of fresh boron nitride surfaces is only 0·03-0·07, but repeated traverses cause increases up to 0·11-0·23. These increases are attributed to the removal of material, due to its softness.

Boron nitride is anisotropic. Some anisotropy is retained in the hot-pressed material. This is indicated by the different values of properties measured in directions both



Screw and bobbin machined from hot-pressed boron nitride.

Crucible of silicon nitride prepared by slip casting silicon in a mould lined with a semi-permeable film and nitriding the cast. In the centre is the film removed from one of the crucibles after drying the cast.

parallel and perpendicular to the direction of pressing.

	Parallel Pressing	*Perpendicular Pressing*
Compressive strength,† p.s.i. ...	45,000	34,000
Transverse strength,† p.s.i.		
at 25°C.	15,880	7,280
at 350°C.	14,800	6,700
at 700°C.	3,840	1,900
at 1,000°C.	2,180	1,080
Modulus of elasticity, p.s.i. × 10^6		
at 25°C.	12·4	4·9
at 350°C.	8·0	3·2
at 700°C.	1·5	0·5
at 1,000°C.	1·6	—
Hardness, Mohs' scale	1-2	

THERMAL PROPERTIES

Sublimation point,† at 760 mm Hg	approx. 3,000°C.
Melting point,† under N_2 pressure ...	>3,000°C.
Stability in H_2†	>2,000°C.

Thermal conductivity,† cal./cm. sec. °C.

	Parallel Pressing	*Perpendicular Pressing*
at 300°C.	0·036	0·069
at 700°C.	0·032	0·065
at 1,000°C.	0·029	0·064

Thermal shock resistance ... good, when dry

Thermal expansion, $°C.^{-1} \times 10^{-6}$

Single crystal,† 41·0 parallel to c-axis, −2·3 perpendicular to x-axis.

Hot-pressed, 0·5-2.0 depending on pressing direction.

ELECTRICAL PROPERTIES—The electrical properties of boron nitride depend strongly on its moisture content. The values quoted are for the dry material, unless otherwise stated.

The resistivity of boron nitride depends to some extent on its treatment before fabrication. Values measured by B.Ceram.R.A. on some of their own material and on some obtained from the Carborundum Co., U.S.A., are very alike and are given below.

Resistivity, ohm. cm., at 300°C.	2×10^{13}
" " " at 500°C.	5×10^{9}
" " " at 700°C.	3×10^{7}
" " " at 1,000°C.	5×10^{5}
" " " at 1,500°C.	6×10^{3}
" " " at 2,000°C.	2×10^{3}

Resistivity values obtained on purified boron nitride are considerably higher than this, up to 10^6 ohm. cm. at 1,300 deg. C. in some cases.

The permittivity varies from 4·15 to over 5 according to temperature and frequency. At low frequencies permittivity increases sharply at temperatures over 450 deg. C. Similarly, the loss factor, which is of the order of tan δ 0·006 at 10 kc/s, rises sharply above 400 deg. C.

CHEMICAL PROPERTIES

Oxidation resistance: boron nitride begins to oxidise at 700 deg. C. in air:

Boron nitride is not attacked by molten aluminium or silicon nor by various molten glasses; these materials do not stick to boron nitride crucibles.

APPLICATIONS—Boron nitride is a machineable electrical insulator which withstands high temperatures in vacuum or inert atmospheres, As such it may find application as an insulator, as a dielectric and as a spacer in electronic valves, etc.

The low friction suggests its use as a low-speed bearing material or as a high-temperature lubricant. Other applications which have been suggested are combustion chamber liners, high-temperature bushings, gaskets and shroud rings, constituents of rocket nozzles, structural material in atomic reactors, internal pump parts for handling certain molten metals, rupture discs for high-temperatures in corrosive atmospheres, and equipment for handling molten glass.

The British Ceramics Research Association is willing to supply samples of these materials to prospective users.

* *Proceedings of the symposium are to be published shortly under the title "Special Ceramics" by Heywood & Co.*

† *Figures quoted from published literature without confirmation.*

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THERMAL STRESSES IN STAINLESS STEEL BOX BEAMS

INTERNAL radiant heat transfer in type 302 stainless-steel box beams has been investigated in the U.S.A. at the National Bureau of Standards to determine the extent to which this mechanism, as distinct from external heat radiation, can alleviate the thermal stresses and deflections that can cause failure in supersonic aircraft and other structures subjected to elevated temperatures. The data show that significant relief may be obtained through maximum internal radiant transfer, a condition that can be achieved by blackening the internal surfaces of the structure. Designing aircraft beam structures to accomplish this effect should lead to savings in weight.

Thermal stress is basically dependent on temperature distribution. The steeper the thermal gradient is, the greater the thermal stress. This means that, for a fairly large difference in temperature between the heated and unheated beam covers, appreciable thermal stresses occur. Internal radiation, however, tends to lower the temperature gradient, and thus relieve the thermal stresses. Increasing the emittance of the internal surface of the heated cover tends to enhance this effect by increasing the rate of radiant heat transfer.

In the present study, the internal radiant heat transfer of thirteen theoretical box beams at high-altitude conditions was computed. These box beams were of three basic types, each varying in wall thickness. Variation with temperature of the thermal and elastic properties of the beam material was considered in the computations. Hemispherical total emittance was taken as 0, 0·35 and 1 for the internal surface and as 0·35 for the external surface—the zero value indicating minimum radiant heat transfer. Changes in the internal radiation were related to temperature distribution, maximum thermal stress and beam deflection.

Good agreement was obtained between the theoretical and experimental values for this beam. In evaluating the effect of a change in emittance on the thermal stress distribution and deflection, the possible effects of yield, creep and buckling were neglected.

The analysis showed that for a thick-walled, slowly-heated beam with a heated cover at 510 deg. C., a change in the interior wall emittance has little effect on the magnitude of the maximum thermal stress. Increasing the interior wall emittance from 0 to 1·0, however, decreases the maximum beam deflection by 34 per cent. For other beams at 650 deg. C., the same change in emittance reduced the absolute maximum stress from 9 to 27 per cent and deflection from 15 to 40 per cent.

The study showed that maximum internal radiant heat transfer, indicated by an emittance value of 1, has an appreciable effect on the temperature distribution, and consequently on the maximum thermal stress and deflection. This effect is particularly marked for a thin-walled, slowly-heated beam.

AMINOPLASTICS
MOULDING MATERIALS

Engineering Materials and Design
DATA SHEET No. 20

MECHANICAL PROPERTIES

	Tensile Strength	Flexural Strength	Young's Modulus in bend	Impact Strength*	Ultimate Crushing Strength
	p.s.i.	p.s.i.	p.s.i.	ft. lb.	p.s.i.
Wood flour filled	7,500–10,500	12,500–16,500	$8–10 \times 10^5$	0·16–0·24	29,000–36,000
Wood flour filled, plasticised	7,000– 9,500	13,000–15,500	—	0·16–0·24	—
Paper filled	7,500–11,500	11,500–17,000	$9·5–10·5 \times 10^5$	0·18–0·34	28,000–35,000
Paper filled, plasticised	8,000–10,500	13,000–16,000	—	0·20–0·25	—
Regenerated cellulose filled	7,000–10,000	13,000–17,000	—	0·14–0·20	—
Melamine resin, paper filled	8,000–10,000	13,000–17,000	—	0·18–0·25	—
Melamine resin, mineral filled	4,000– 6,000	6,000–11,000	—	0·12–0·22	—

*¼-in. notched specimen.

ELECTRICAL PROPERTIES

	Surface Resistivity	Volume Resistivity	Electric Strength		Power Factor	Dielectric Constant
			Mld. from cold powder	Mld. from preheated powder		
	ohms	ohms/cm.	volt/mil.	volt/mil.	at 10^6 c/s	at 10^6 c/s
Wood flour filled	$10^{11}–10^{13}$	$10^{12}–10^{13}$	20– 80	80–180	—	—
Wood flour filled, plasticised	$10^{11}–10^{13}$	$10^{12}–10^{13}$	50–100	100–200	—	—
Paper filled	$10^{11}–10^{14}$	$10^{12}–10^{14}$	50–140	120–220	—	—
Paper filled, plasticised	$10^{12}–10^{14}$	$10^{12}–10^{14}$	170–220	190–240	—	7–9
Regenerated cellulose filled	—	—	30–70	70–130	—	—
Melamine resin, paper filled	$10^{12}–10^{14}$	$>10^{13}$	70–130	130–190	—	—
Melamine resin, mineral filled†	$10^{12}–10^{14}$	$10^{13}–10^{14}$	130–250	200–280	0·035–0·55	4–6

†Improved electrical properties at high temperatures.

GENERAL PROPERTIES

	Specific Gravity	Cold Water Absorption	Boiling Water Absorption	Appearance
		mgm.	mgm.	
Wood flour filled	1·5–1·6	40–100	250–500	Opaque
Wood flour filled, plasticised	1·5–1·6	50–90	300–450	Opaque
Paper filled	1·5–1·6	25–90	200–400	Translucent or opaque
Paper filled, plasticised	1·5–1·6	30–40	250–350	Translucent or opaque
Regenerated cellulose filled	Approx. 1·5	50–100	300–600	Highly translucent
Melamine resin, paper filled‡	1·50–1·55	10–30	50–90	Semi-translucent or opaque
Melamine resin, mineral filled	1·8	7–14	15–40	Grey-brown

‡Hot water resistant.

The composition, treatment and testing requirements for aminoplastic moulding materials are set out in B.S. 1322: 1956.

Data sheet by Yarsley Research Laboratories Ltd.

EMD 1314 for further information

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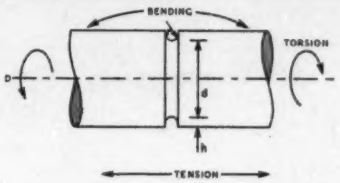
EMD 1315 for further information

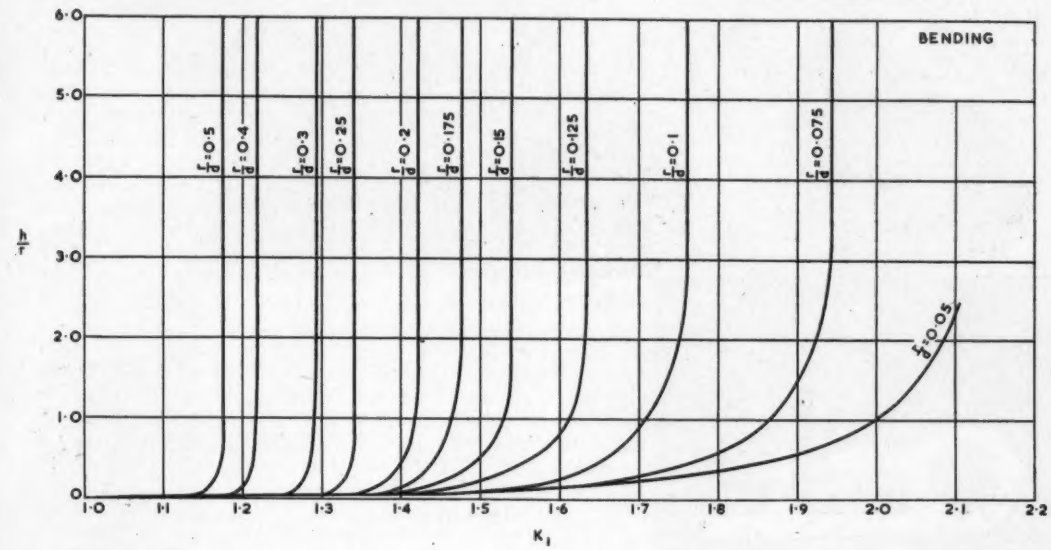
Engineering Materials and Design

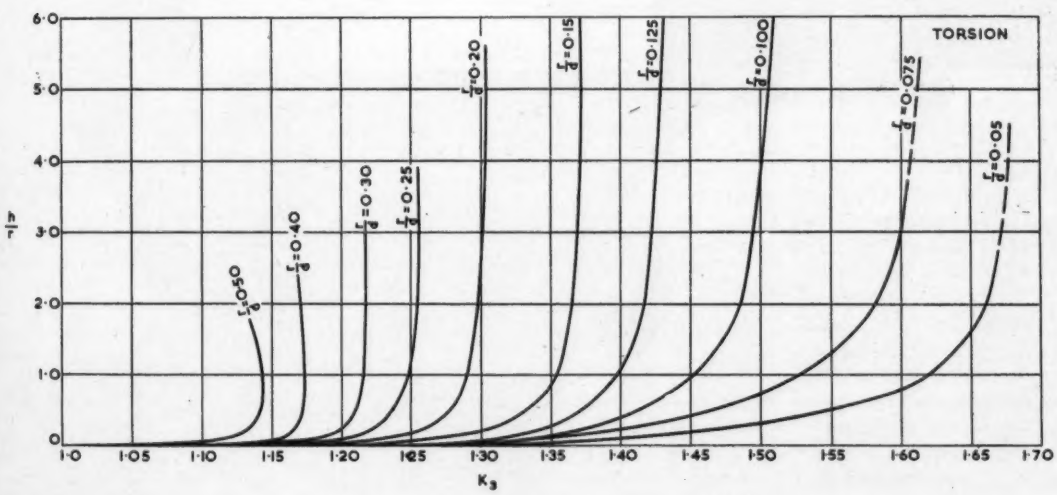
DATA SHEET No. 21

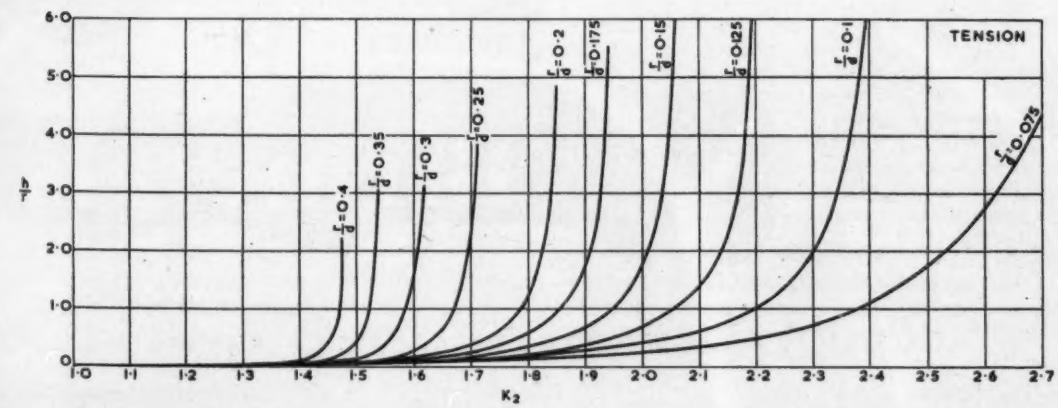
STRESS CONCENTRATION FACTORS FOR A U-NOTCH IN A CIRCULAR SHAFT

Abrupt variations of stress distribution due to a change in a cross-sectional area cause stress concentrations. The following factors are given for conditions of bending, torsion and tension loads, and are a measure of the increased local stress.









Data sheet by H. Vincent, B.Sc., A.F.R.Ae.S.

EMD 1316 for further information

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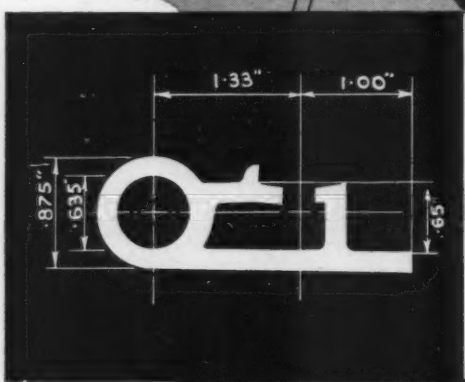

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NEW GLASSES FOR ELECTRICAL USE

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A GROUP of glasses which melt and become very fluid at temperatures between 125 and 350 deg. C. has been developed by Bell Telephone Laboratories. The low viscosities of the molten glasses predict their suitability for encapsulation of semi-conducting devices, capacitors, resistors and printed circuit boards.

Containing varying proportions of sulphur or selenium and the heavy metals arsenic and thallium, the glasses range electrically from semi-conductors to insulators. Resistivity ranges from 10^6 to 10^{14} ohm-cm.

Chemically, the glasses have about the same durability as glasses in general. They are insoluble in water, dilute alkalis, acids and organic solvents, but are attacked by concentrated alkalis. Several of the compositions are stable to air oxidation at temperatures above 250 deg. C.

The glasses show good wetting of most metals. Thermal expansion coefficients range from 20 to 50×10^{-6} per deg. C. Thermal conductivities are of the order of 0·0007 cal./sec./sq. cm./deg. C./cm. The glasses are also unusual in that they can be evaporated and condensed as thin glass films. The selenium-containing compositions bond particularly well to ceramics and the silicate glasses.

Silicon Carbide Foam Developed

A new high-temperature thermal insulation material, silicon carbide foam, is now in pilot-plant production at the Carborundum Co. Suitable for use at temperatures up to 2,200 deg. C. in an inert atmosphere, 1,650 deg. C. in oxidising atmospheres, the material is available in low densities of 0·25-0·30 gm./cu. cm., and higher densities of 0·50-0·60 gm./cu. cm.

Suggested uses for the material include thermal insulation in nuclear reactors, furnaces, missiles and non-ferrous metallurgy. The open-cell structure also suggests the material's use as catalyst supports and in hot gas or corrosive wet filtration. The material is machinable with standard steel cutting tools and can be fabricated to close tolerances.

The foam is made from self-bonded silicon carbide and thus is highly resistant to most corrosive chemicals and some molten metals. Low-density foam resists compressive loading of 85 p.s.i.; higher density types resist compressive loading of 750 p.s.i. Thermal conductivity over a temperature range of 430-1,040 deg. C. is 6-8 B.t.u./sq. ft./hr./deg. F./in. for low-density types, 11-14 for higher density types.

Low-temperature Polyethylene Copolymer

A new polyethylene copolymer with outstanding low-temperature toughness has been developed by Union Carbide Plastics Co. and is commercially available. In comparison with polyethylenes of similar density and melt index, the injection moulding grade, designated DPD-7365, is also said to have five times greater flex life and superior environmental stress crack resistance.

Brittle temperatures as measured by A.S.T.M. D746 are −70 deg. C., 50 per cent failure; −60 deg. C., 20 per cent failure. Large outdoor garbage cans moulded of the material have withstood without damage crushing by a 16-ton truck at −12 deg. C. At −23 deg. C. cans easily withstand 6-ft. drop tests.

The material has a density of 0·935 gm./cu. cm., melt index of 8 gm./10 min., secant modulus of 40,000 p.s.i., tensile strength of 1,600 p.s.i., yield strength of 1,500 p.s.i., and elongation of 210 per cent.

Although the monomer other than ethylene has not been disclosed, it is said to be radically different from that used in previously announced polyethylene copolymers.

Flexible Inorganic Films as Dielectrics

Recent discoveries at Bell Telephone Laboratories have shown that inorganic fluoride coatings can be formed on metals to provide a flexible and porous-free insulation with good dielectric properties at high temperatures. It is hoped that the new insulations can provide the answer to some of the problems in missile re-entry guidance systems, as well as other more earth-bound high-temperature applications.

The insulating coatings are produced directly on copper, aluminium (and some other metals) by exposing them to oxidising carriers of fluorine such as hydrogen fluoride or elemental fluoride at temperatures from 300-600 deg. C. The thickness of the resulting copper fluoride and aluminium fluoride films depends on the concentration of fluoride, processing temperature, and time of exposure. Aluminium fluoride, for example, forms a fluoride film one micron thick in a few minutes at 550 deg. C. The film adheres even when bent repeatedly at a 90-deg. angle.

Electrical insulation values are very high for both copper and aluminium films—about 10^{10} and 10^{11} ohms at room temperature for films 1-2 microns thick. The films retain their insulating properties at high temperatures. Aluminium fluoride films exhibit a resistance of about 7×10^9 ohms up to 500 deg. C. and show no tendency to oxidise even above 600 deg. C. The insulation does not break down at 450 volts at 500 deg. C. and shows no tendency to hydrate or dissolve at high humidity.

Heavy Coatings by Vacuum Metallising

Vacuum metallising is normally used to produce extremely thin decorative coatings. However, a newly announced process by the National Research Corporation now permits pure aluminium coatings to be deposited in thicknesses up to 2 mil. on a variety of metals for corrosion-resistant applications. Typical metals that have been coated include high-tensile strength steels, cold rolled steel, aluminium die castings and forgings, titanium, magnesium and cast iron. The coatings can be anodised to provide excellent wear resistance as well as attractive colouring in a number of metallic pastel and dark shades.

Preliminary estimates show that the vacuum metallising process can be commercially competitive with conventional electroplating. A large aircraft manufacturer has tested the heavy coatings up to 1,400 hr. in 20 per cent salt spray and salt fog without failure. Tests also indicate that the process eliminates the hydrogen embrittlement of steels sometimes encountered in conventional electroplating of aircraft and missile components.

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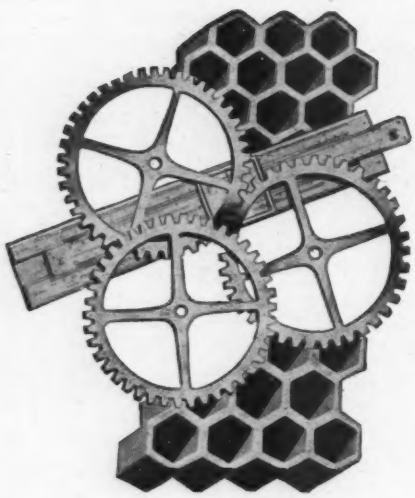

22—26 FEBRUARY 1960

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Russian Stepless Gear – Can it Really Work?

Sir,

In a very interesting article in your July issue, a stepless transmission gear is described as providing for "infinitely variable changes in the speed". In my opinion, the device described will not work, the fallacy lying in the last sentence of the first section (page 368) which says: "The transition will consequently be smooth, especially since the pinion has an even number of teeth with slightly bevelled tips."

Consider the right-hand view of Fig. 5 of the article and imagine the pinion being inserted along its axis between the two opposed racks; it can be entered only at a series of special positions, differing in radial distance from the driving shaft centre line by intervals of one tooth pitch. Each of these positions will give a fixed ratio expressible as an exact fraction, and at intermediate positions the mechanism will lock solid.

In general, no infinitely variable speed gear can work without at least one pair of components which can be locked together, instantaneously or for a finite time, in an infinite number of relative positions, such as a wheel and cone, belt and pulley, two parts of a clutch or freewheel or a valve and a body of fluid. The device described contains no such components, and so can produce only a finite number of fixed ratios.

M. J. French

81 Alric Avenue,
New Malden, Surrey.

Could be Simpler

Sir,

I was very intrigued at first by the Russian variable-speed gear, but:

The drive is intermittent, with periodic speed fluctuations.

Although the lower view of Fig. 7 shows signs of realism, the other two do not. They are only diagrammatic, and I am willing to bet that the gear has never been made in a satisfactory form.

It is an extreme case of a bad overhang/guided length ratio. The only thing that maintains the orientation of the ring (2) of Fig. 2 is the tooth face width of the pinion; far too little length for this.

In other words, I don't think much of it. I believe the same result could be obtained from a simpler mechanism.

Hugh Clausen

17 Harman Drive,
London, N.W.2.

Not Infinitely Variable

Sir,

With reference to your article "Stepless Transmission Gear with Constant Mesh" in your July issue, I would like to offer the following remarks.

Whilst I agree that the basic principle of the gear (using a single disc and pinion) will give a sinusoidal output with infinitely variable amplitude within the physical limitations of the mechanism, I do not feel that infinite variation is possible in the case of the complete reduction gear as shown in your article.

My reason for this doubt is as follows: If there is to be infinite variation between minimum and maximum transmission ratio, then the pinion must be capable of working at any radius on the disc between its minimum and maximum dictated by the physical limitations of the complete reduction gear. The arrangement of gears as suggested in your article, however, does not permit this freedom of position, because, in order that the pinion may pass smoothly from one rack to the other, its centre must be at such a position that the teeth line up with the tooth spaces. There are only certain positions of the pinion centre which will permit this and these positions are spaced at one-half tooth pitch intervals. This means, therefore, that there must be definite steps in the transmission ratio, their number depending on the pitch of the gears and the physical sizes of the racks and pinion.

As is pointed out in your article, the width of the pinion must be kept wide in order to achieve any useful efficiency figure. This pinion width, however, is an embarrassment when the pinion is trying to move from one rack to the other, due to the fact that the pinion should enter the rack which it is about to engage before the rotation about its own axis has ceased. This means, therefore, that backlash must be built into the meshes, which is an undesirable feature when considering the direction reversals which occur in operation. I would be pleased if you would accept these remarks, and be good enough to let me have your comments in due course.

S. T. Tottey

79 Belmont Lane,
Chislehurst,
Kent.

"Interesting Monstrosity"

Sir,

The stepless transmission of Russian origin featured in your July issue is an interesting but complicated monstrosity. Precisely the same result could be obtained with the far simpler mechanism shown in the accompanying drawing. But who wants an infinitely variable gear with a sinusoidal output defeats me.

H. Barrett

London, S.W.3.

EDITOR'S NOTE

The Soviet engineer's design for a stepless transmission mechanism embodying a constant mesh which was described in our July issue aroused considerable interest—as the selection of letters here indicates.

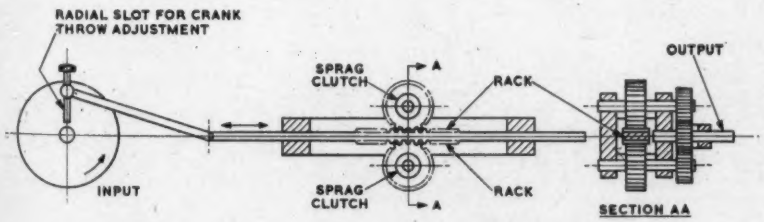
The version of the gear which is illustrated in basic principle in Fig. 5 (page 368, July issue) relies upon the pinion having considerable width. This being the case, it is certainly true that alteration of the gear ratio would not be possible when the pinion happened to be engaging both racks, as it would at the point of zero rotation. Assuming that the racks are semi-circular, it would be necessary to have a very narrow pinion. If such a pinion were used, it would be unworkable for the reasons given by Mr. Clausen.

It is possible, however, that this objection might be overcome by having either:

1. *Two discs side by side.*
2. *A single disc with half racks on each side.*

In both cases, however, it would appear that the output would necessitate an elaborate differential, as in the original.

The terse contribution from Mr. Barrett is therefore particularly interesting. For it to be absolutely positive, however, there would have to be no backlash in the rack and pinion mechanism and perfect engagement of the sprag clutches.



This mechanism is suggested by one reader (H. Barrett) as achieving far more simply the same result as the Russian gear.

New Books

Optical Properties of Semiconductors. *By T. S. Moss. (Butterworths, 50s.)*

THIS book is one of a series of monographs dealing with specific properties of semiconductors and written by specialists in the particular fields covered. In the present book the author has defined his aim to be that of producing an up-to-date summary and review of present knowledge about the optical properties of semiconductors. The treatment is not exhaustive and excludes applications and devices; but, even so, the terse style adopted in the text indicates the effort required to keep the size and cost of the book within tolerable limits. Over 600 references are listed and the latest are for August, 1958. The first six chapters are devoted to establishing a theoretical framework based on classical electromagnetic and dispersion theory as well as the energy band theory of solids. Although brief, these chapters are remarkably comprehensive. The remaining ten chapters deal with the optical properties of actual semiconductors, both elemental and compound, mainly in terms of refractive index, absorption and photoconductivity. Germanium, silicon and indium antimonide are among the materials discussed.

Dr. Moss has certainly succeeded in his aim of providing a broad picture of the contemporary position. Where more detail is required there are adequate references to follow up. A useful addition, however, would have been a final summing up of what has been achieved and what remains for future work to achieve. To anyone concerned with the optical properties of solids, this book fills a gap in the literature and would be a valuable investment.

D.S.

Intermediate Engineering Drawing. *By A. C. Parkinson. (Pitman, 12s. 6d.)*

This, the fifth edition of this well-known work, is intended for second-year National Certificate courses and is copiously illustrated with the kind of drawing problems the young draughtsman will encounter, together with calculations where these are necessary. A number of the illustrations have been redrawn to bring them into line with B.S. 308:1953, in some cases views being rearranged to convert them into third-angle style in view of the increased use of this system. A completely different presentation of the material on limits and tolerances has been made.

Progress in Dielectrics. *Edited by J. B. Birks and J. H. Schulman. (Heywood, 70s.)*

This book is the first of an annual series of volumes intended to co-ordinate current knowledge of dielectric phenomena, materials and techniques.

In the first four chapters of the book the emphasis is on dielectric breakdown and on the insulating properties of solid, liquid and gaseous dielectrics. A comprehensive review is given of the several mechanisms of dielectric breakdown in solid insulation and the important practical question of insulation-testing procedures is also discussed. The second chapter describes the intriguing and complex breakdown effects that occur in single crystals, including some interesting photographs showing the details of surface breakdown; recent studies of pure hydrocarbons are emphasised in the chapter which deals with the electric strength, breakdown time-lag and high field conductivity of dielectric liquids and the review of the practical aspects of the use of gaseous insulation refers particularly to the electronegative gases.

The ferro-electric properties of barium-titanate crystals are classified and the substantial progress that is being made towards a unified thermodynamics theory is described. An interesting chapter on non-oxide ceramics reviews the elements and binary compounds as potential ceramic dielectrics revealing certain trends in their properties and focusing attention on the non-metallic nitrides. The final article describes the theory and practice of electro-phoretic deposition of insulation, a technique which may prove suitable for wider application in the future.

Solid Propellent and Exothermic Compositions. *By James Taylor. (Newnes, 25s.)*

Like many of the compounds listed, this book contains a curious and fascinating mixture, and many schoolboys' eyes will glisten at the pages giving formulæ for rocket fuels and fireworks.

It is not, however, an elementary book, since parts are of a highly technical nature, and range over subjects varying from exothermic chemical reactions, explosives, propellents, rocket motors and gasless reactions. Each subject is discussed from many aspects, and an historical background adds interest to what the author fairly describes as a book on chemicals as a source of energy.

Ball and Roller Bearings — Theory, Design and Application. *By Eschmann, Hasbargen and Weigand. (Heyden, 56s.)*

Presentation of the subject-matter in this book is as concise and polished as the components with which it deals, and it is doubtful whether any other precision part has been dealt with so adequately. Translated from the German, the fundamentals are based on German practices, standards and specifications, and to facilitate conversion to English standards, where this is required, two supplementary folders give the necessary factors, either graphically or as formulæ.

The thoroughness with which these authors deal with design principles, bearing types and calculations is particularly welcome. Of special interest is the chapter dealing with life ratings of races. Chapters dealing with fits and tolerances comprehensively cover not only the practical aspects but also the stresses imposed and their consequences. Lubrication is given an equally detailed treatment, together with fitting and removing races, and examples of characteristic bearing failures.

Concrete Practice. *By Charles H. Hockley (Chatto & Windus, 12s. 6d.).*

A practical book of value to those who supervise building work, this work will also interest the apprentice in structural engineering. The merits of prestressed and reinforced concrete are discussed, and the tables of hardness times, types of aggregates and the practical interpretation of stresses involved should make this a popular reference book.

Fluorocarbons. *By Merritt A. Rudner (Chapman & Hall, 46s.)*

This is the sixth of a series of Reinhold publications dealing with plastics. As with others in the series, no specialist chemical knowledge is required to understand the book, which deals with the properties and processing techniques of fluorocarbons in a practical manner. It should therefore be of interest to engineers and designers who require a short book of reference dealing with materials of increasing importance.

In fact, the book deals only with the two basic types of fluorocarbon commonly available, i.e., p.t.f.e. and p.c.t.f.e., and the data presented are classified largely under specific trade names such as Teflon, Fluorothene, Kel-F, etc.

The book abounds with helpful charts, tables and processing data.

Finishing Handbook and Directory. *Edited by C. S. Woollard. (Sawell Publications, 37s. 6d.)*

To this 1959 edition a new chapter has been added on phosphating, and there are new sections dealing with latest developments in polyester finishes and curtain coating. The existing sections of this very useful handbook deal—in a volume of some 500 pages—with anodising, electroplating, flock coating, galvanising and sherardising, marking, metal cleaning, polishing and spraying, paints, plastics coatings, sanding, stripping, vacuum deposition, vitreous enamelling, etc.

Using Steel Wisely. *By Leslie Aitchison and William I. Pumphrey. (MacDonald & Evans, 45s.)*

This book is described by its sub-title as "a dissertation on the principles underlying the selection of the correct steel for any engineering application". The style of presentation is to be commended, for it is easy to read and understand. One notable feature is the clarity of the illustrations and their reproduction, particularly in the early chapters dealing with ingots and hot forming; faults and effects of various treatments are clearly shown by these.

Section 15 may be regarded as an encyclopædia of terms used in design, clearly defined and elaborated.

SCOTTISH INDUSTRIES EXHIBITION

Preview of some exhibits to be seen from September 3—19 at Kelvin Hall, Glasgow

Spherical Journal Bearing

A new spherical journal bearing just introduced is a self-contained, self-aligning assembly for general engineering. It is said to use a new principle whereby the bearing surface is spherical, and this enables a single bearing surface to carry both journal and thrust loads.

The bearing consists of two sub-assemblies. One is the sphere, which is in halves with a hole to suit the appropriate shaft size; this sphere is clamped to the shaft and may rotate with it or have freedom for axial movement. The other sub-assembly is the bearing housing and this incorporates a lubricant sump and has a flanged base for mounting. The housing is also split, for assembly.

These bearings are stocked in standard shaft sizes of 1-4 in. diameter, or larger to order. Typical applications are expected to be fan, transmission or motor shafts. No maintenance is said to be needed other than topping up with oil at long intervals. Glacier Metal Co. Ltd.

EMD 1429

Furnace with Closed Quenching

A new type of furnace being featured is a vertical cylindrical atmosphere furnace combining the advantages of pit-type gas carburisers with facilities for closed quenching hitherto available only in horizontal equipments. The furnace has a vertical cylindrical heating chamber, closed at the top, with provision for inserting a charge through the base. The chamber can be electrically heated or gas fired with radiant tubes. A powerful fan draws the atmosphere up through the charge and forces it down over the heating elements, ensuring uniformity of heating and intimate contact of the atmosphere with all surfaces of the charge.

A feature of the furnace is the use of a charge trolley to move the charge horizontally from the outer loading table into the purging vestibule and to and from the furnace bung. The trolley runs on rail tracks and has wheels mounted on ball bearings. Built into the trolley is a raising and lowering mechanism operated from outside the furnace with a removable push rod. The trolley can be inserted through a swinging counter-balanced flap on the outer door. After use in the furnace the trolley is lowered and withdrawn. Efco Ltd.

EMD 1430

Large Tapping Attachment

On show for the first time at the exhibition will be a tapping attachment which is claimed to be probably the largest in the world manufactured on a mass-production basis. The tool will tap 2½ in. Whitworth, 90 per cent thread, in 60 t.s.i. tensile steel, using a single plug tap, at 75 r.p.m. Clydeside Machine Tool Co.

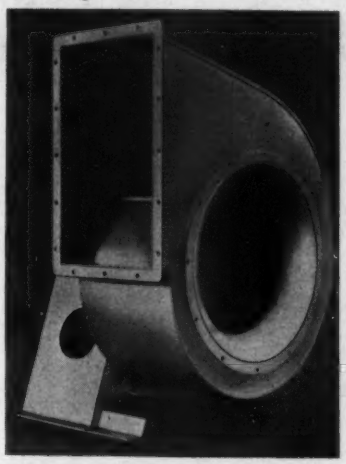
EMD 1431

Brushless Alternator

A brushless alternator is now available in this country that has no brushes, slip rings, commutators or external control gear. It is of the revolving field, non-salient pole, type of construction, and the supply to the field is from an exciter which is in itself a small revolving armature machine. The three-phase output from the exciter is fed directly to rectifiers which rotate with the shaft, and the output of the rectifiers supplies the main alternator field. The exciter field is supplied by a transistor preamplifier. The equipment has a rating of 10-150 kVA. at 1,500 r.p.m., three-phase, three or four wire. Macfarlane Engineering Co. Ltd.

EMD 1432

Centrifugal Fan



The recently introduced Aristocrat centrifugal fan for heating, ventilating and air conditioning is one of a range of four sizes which are available with either V-rope or direct motor drive. The makers claim it embodies a new concept of fan manufacture providing for a rigid casting with a new method of stiffening. The robust construction of the forward curved impeller excludes the necessity for either centre spider or tie rods. Keith Blackman Ltd.

EMD 1433

Bellows Expansion Joints

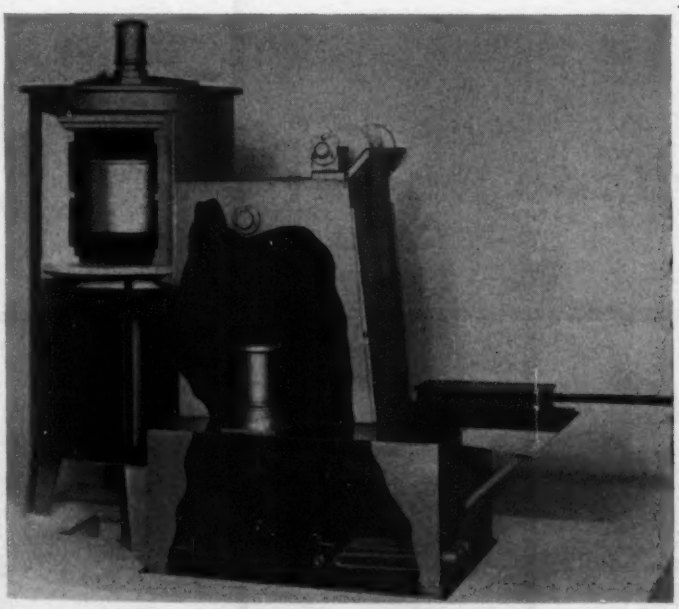
A range of packless expansion joints has been developed to give flexibility in a wide variety of applications. These units are made 1½ in. to 7 ft. in diameter, and in such metals as stainless steel, chromium, molybdenum, alloy steels, copper alloys, etc., to suit the specific purpose. They can be designed to absorb not only axial expansion, but vibration, angulation, lateral movement, and any such stress liable to be set up in a pipeline. They are made by a special hydraulic forming process which obviates a large number of structural welds. Munro & Miller Ltd.

EMD 1434

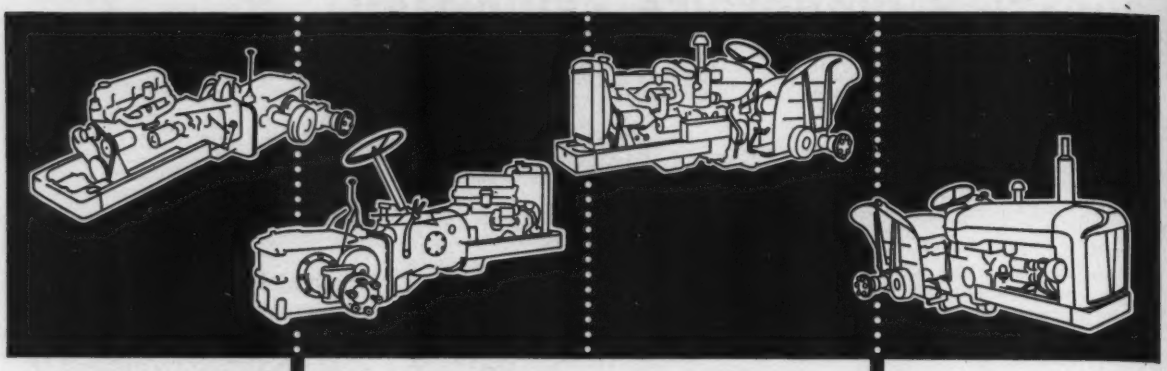
Copying Paper

A product of particular interest is a special brand of paper known as N.C.R. These initials stand for "no carbon required", i.e., no carbon sheets are necessary to produce simultaneous copies of a typed document or letter. N.C.R., which resembles ordinary paper in appearance and to the touch, would appear to have possible applications in drawing offices. Wiggins Teape Group.

EMD 1435



Model of the new Efco furnace, described above.



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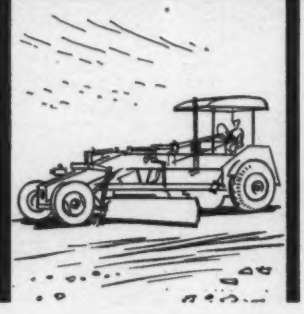

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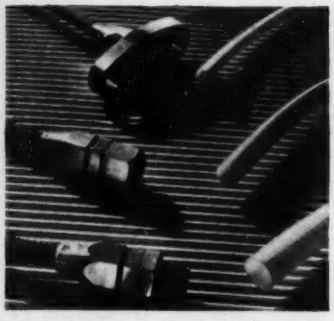
WHAT'S NEW IN MATERIALS & COMPONENTS

P.T.F.E. Flexible Hose

Hose made from p.t.f.e. is claimed to have a working temperature range of −80 to +250 deg. C. and in some conditions as high as 300 deg. C. It is said to retain its toughness and excellent weathering properties throughout this range, and is also said to be impervious to water and



steam. With ¼-in. bore a working pressure of 5,000 p.s.i. can, it is said, be achieved, while a bore of 1 in. withstands 2,500 p.s.i. By the addition of multi-braiding even higher pressures up to 20,000 p.s.i. are claimed to have been reached. The present range of rod and flexible tube is ¼-in. to 1-in. bore, but larger sizes could be produced specially. A patented fitting is also supplied to facilitate end connections to the hose. William Rose Ltd.

EMD 1387 for further information

Ceramic Coating

Unikote is a ceramic for coating metals and other materials. It is available in a range of types (alumina, zirconia, rutile, etc.) and it is said that almost any material can be coated, provided it has a melting point higher than 150 deg. C. Thicknesses of 0·002 in. and upwards can be flame-sprayed by the manufacturer and the finish may be rough, matt, smooth or polished. Porosity is said to be zero for a sealed coating or 5-10 per cent for an unsealed one, and the temperature range of the finished coating is claimed to be −100 to +1,000 deg. C. Suggested uses are protection against wear, corrosion, abrasion, heat, moisture or blast shock. It can also be used as electrical insulation. United Insulator Div., T.C.C. Ltd.

EMD 1388 for further information

H.D. Polyethylene Powder

Powder for dip-coating made from Ziegler-type high-density polyethylene is now on the market. Telcothene H.D. powder, as it is called, while possessing the same chemical resistance and anti-corrosive properties as the well-established Telcothene powder, is claimed to have several advantages deriving from the greater mechanical strength and rigidity of high-density polyethylene, though it also has certain limitations where the appearance of the coating is of prime importance. Its physical properties, including the higher density itself, are bound up with its chemical structure, the molecular chains being linear rather than branched, and therefore more closely packed together.

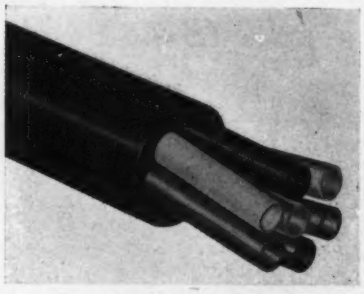
The softening point of high-density Telcothene is about 20 deg. C. higher than that of conventional Telcothene, and coatings may be kept in contact with boiling water for short periods, though the long-term working temperature may not exceed 80 deg. C. Alternating contact with hot and cold water over a long period should be avoided. The tensile strength is said to be much superior and the hardness considerably greater.

Permeability to moisture is particularly low. It resists—and to a greater degree—attack by all chemicals to which conventional Telcothene is resistant. Telegraph Construction & Maintenance Co. Ltd.

EMD 1389 for further information

Cabled Nylon Tubes

A British company announce that, in addition to their cabled copper tubes, they are now manufacturing a range of cabled



nylon tubes. Typical applications include the remote monitoring of processes and equipment in chemical plants and oil refineries by pneumatic or fluid-operated meters and other indicating devices. The tubes, of which there may be 1, 3, 4, 7, 12 or 19 in a "cable", are identified by colour. They are laid up in electric cable fashion and sheathed overall with p.v.c. or neoprene. If desired, they can be provided with steel wire armour protection.

No special type of support is required for these cabled nylon tubes; cable clips of tinned brass or corrosion-resistant metal are suitable for the smaller 1-, 3-, 4- and 7-tube assemblies, while special cast light-alloy claw-type cleats may be used for larger sizes and for groups of tubes. These tubes are arranged so that they can be used with the standard fittings now generally available. B.I.C.C. Ltd.

EMD 1390 for further information

Miniature Thermocouple Wire

A new miniature thermocouple wire with an outside diameter of only 0·5 mm. is the latest addition to the Thermocoax range of ceramic-packed thermocouple wires now available in the U.K. Known as the 2AB Ac 05, it has an outer sheath of 18/8 steel and cores of Chromel/Alumel insulated from each other and the sheath by powdered magnesium oxide.

Temperature range is stated to be 0-900 deg. C. and an accuracy of 2.8 deg. C. up to 350 deg. C. and of 0·75 per cent from 350-1,000 deg. C. is claimed together with good stability, short response time, great mechanical strength and excellent electrical insulation. It may be bent on a radius of 1 mm.

A new 1-mm. Thermocoax with Inconel sheathing is also available with greater resistance to corrosion than the standard 18/8 steel sheath type. Another innovation is a box of accessories for facilitating the correct forming of thermocouples and for protecting the couple itself against corrosion. Research & Control Instruments Ltd.

EMD 1391 for further information

Rubber Conduit Strip

A new type of conduit for temporary leads, designed to increase safety on industrial and business premises, has been developed for use where pedestrians, trolleys, fork-trucks and other light vehicles run over temporary leads. Known as Vulcascot rubber conduit strip, the maximum length in which this can be produced is 30-ft. rolls. Vulcascot (Gt. Britain) Ltd.

EMD 1392 for further information

Pretreatment Solutions

A range of phosphating solutions and pickling solutions which may be used without prior degreasing of the metal is now available. This latest development is said to constitute a major advance in the metal treatment field, offering the possibility of tremendous savings in equipment, space, time and materials.

Phosphating solutions employing the new technique are available for corrosion, electrical and heat-resistant finishes, for paint bonding and for deep-drawing lubricant coatings. Hellermann Ltd.

EMD 1393 for further information

FOR MORE INFORMATION
about any of the products mentioned on these pages, please use the special reply card bound in this issue.

READERS' ADVISORY SERVICE
We shall be pleased to help readers who have difficulty in tracing sources of supply of materials or components.

Transistor Holders

As transistors begin to replace valves, the demand arises for a transitor mounting. A range of transistor mountings is now being manufactured, moulded in Helvin p.v.c., which easily and effectively clips transistors to printed circuit boards or the conventional chassis; the bollard in the base of the moulding is simply pushed through a small hole in the panel and the transistor is held firmly in place. The holder has the additional advantage of insulating the metal can of the transistor.

There are four sizes to fit different panel thicknesses (this dimension is included in brackets in the part number): $\frac{1}{32}$,$\frac{1}{16}$,$\frac{3}{32}$ and $\frac{1}{8}$ in. Hellermann Ltd.

EMD 1394 for further information

Plastics-coated Steel Strip

A new plastics-coated steel strip is now available in a large range of colours and textures. It is said to be extremely durable and corrosion proof and that the strip may be formed without damage to the coating.

Available in widths from 1-11 in. in thicknesses of 0·020-0·080 in., lengths of up to 12 ft. may be obtained. Alternatively, it is supplied in coil form up to 30 cwt. It is believed to have applications in many engineering industries for automobiles and domestic appliances, as well as in railways and ships. British Rolling Mills Ltd.

EMD 1395 for further information

Fluoro Elastomer

The development of Viton was influenced by the increased need for flexible construction materials with higher heat resistance. Its most valuable properties are claimed to be (1) dependable performance at temperatures of 200 deg. C. and up; (2) resistance to most oils, chemicals, solvents and exotic fuels at temperatures of 200 deg. C and above; (3) good mechanical properties; and (4) excellent resistance to ozone, oxygen and weathering.

It is said to resist temperatures up to 230 deg. C. in continuous service and up to 320 deg. C. in intermittent service. Suggested applications are for use in precision seals, diaphragms, coated fabric and linings. Du Pont & Co. (U.K.) Ltd.

EMD 1396 for further information

Metallic Lead Primer

Pitan metallic lead primer is claimed to form a blanket of metallic lead on iron and steelwork and to seal the surface from electrochemical activity—the main cause of corrosion. Additionally, the metallic lead, plus the oil in the film, forms lead soaps which combine to give excellent adhesion and restrict the spread of any corrosion still present on the surface being treated. Traces of firmly adherent rust are said to have no deleterious effect on the performance..

By virtue of its excellent flow-out properties, this primer is said to eliminate the danger of corrosive attack at the area of low film thickness occasioned by bad brush marks and poor levelling properties found with many other metal primers. Allweather Paints Ltd.

EMD 1397 for further information

H.D. Polyethylene Sheet

Sarolene type H is a new polyethylene sheet manufactured by the extrusion process from high-density, high-molecular weight rigid polyethylene produced by the low-pressure process.

It is claimed that the sheet can be readily thermoformed and fabricated, which makes it suitable for an enormous range of interesting products which have been impossible to manufacture to date from existing raw materials.

To avoid waste in use, the sheet can be supplied in any size up to 100 × 48 in. in the thicker gauges and in continuous rolls in the thinner gauges. All gauges from 0·010-0·250 in. are available. Thicker gauges can be supplied to special order. Saro Laminated Wood Products Ltd.

EMD 1398 for further information

Plastics Valves

These valves, being made entirely of plastics without any metal parts, are claimed to be ideally suitable for acid runs and installations where corrosion precludes metal. A range of sizes, from nominal pipe size $\frac{1}{4}$ in. upwards, and plain, threaded or flanged entry are available. Barflo Ltd.

EMD 1399 for further information

Stiff Plastics Mesh

A new mesh, produced in roll or sheet form, similar to metal mesh, is now made from Rigidex polyethylene and is claimed to offer many distinct advantages. It is said to have very low specific gravity (0·96) and is thus only one-third the weight of a corresponding aluminium mesh and less than one-eighth the weight of mild steel. In all thicknesses the mesh is flexible enough to be handled very easily, and in thicknesses above $\frac{1}{4}$ in. it is sufficiently stiff to be self-supporting.

The mesh is said to have a comparatively high strength/weight ratio and to

be virtually indestructible. The inertness of the polyethylene from which it is made means that very few substances will adhere to it even temporarily, and the mesh is thus very easy to clean.

Suggested uses for the new mesh include guards for electric motors operating in corrosive conditions, battery separators, grilles and screens in chemical plants and laboratories and filtration supports. Expanded Metal Co. Ltd.

EMD 1400 for further information

Epoxy Laminate

Details of two new grades of epoxide/glass laminates—DH. 19073 Natural and DH. 19074 Natural—have recently been announced.

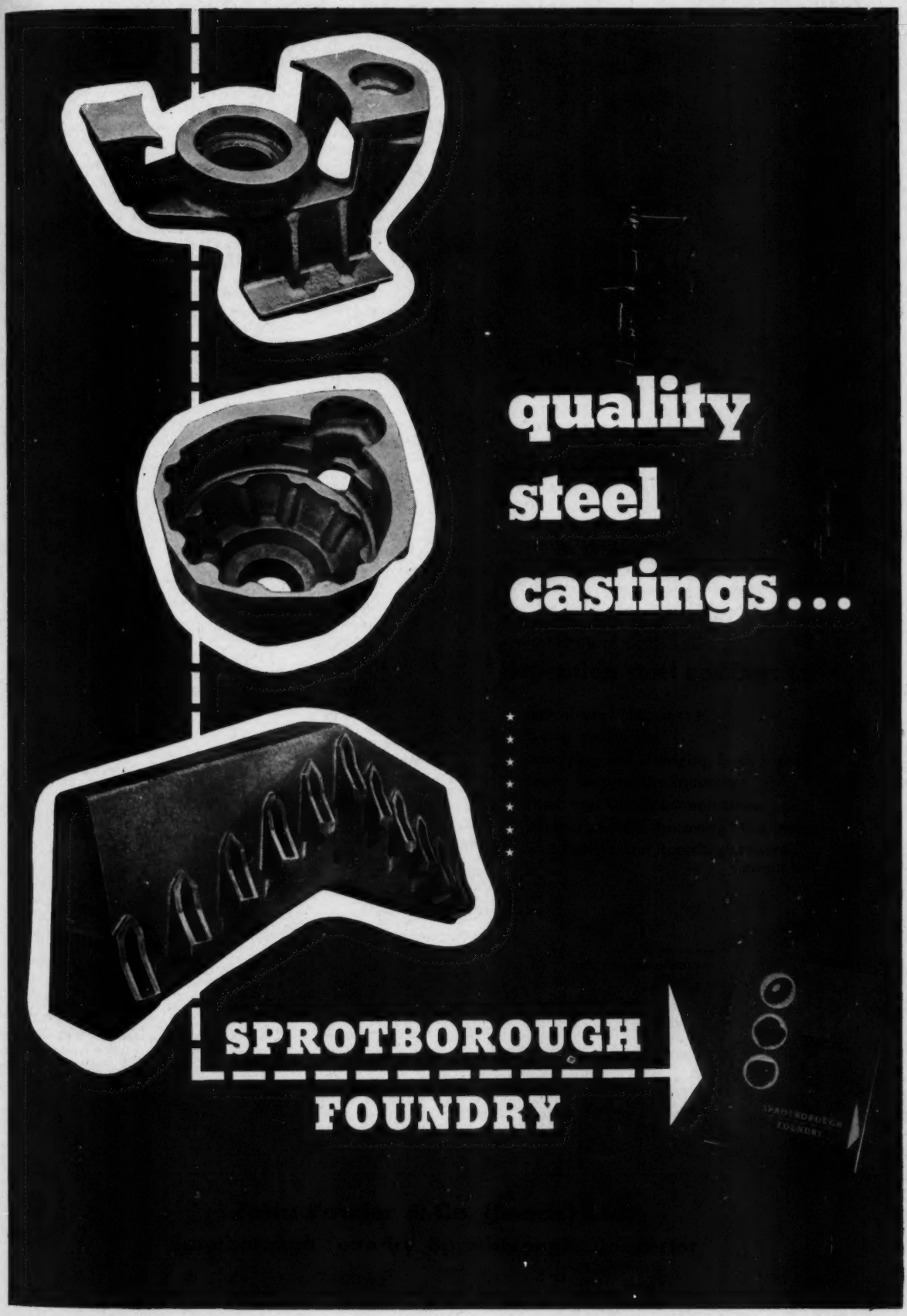
DH. 19073 Natural is said to have excellent mechanical strength and water resistance coupled with good electrical properties. Two copper-clad versions of it are available: the first with 1 oz. (0·0015 in.) copper-foil on one or both sides and the second with 2oz. (0·003 in.) copper-foil. Bakelite Ltd.

EMD 1401 for further information

Fluorinated Elastomer

Fluorel elastomer is a new high-temperature, highly fluorinated synthetic rubber developed for long service under severe temperature and corrosion conditions. In many applications, it is claimed, Fluorel can perform at temperatures between 200 and 320 deg. C. Its composition and molecular weight have been carefully controlled to combine easy processing with unusually high mechanical strength, fuel and solvent resistance, and thermal stability. In addition to these properties, its non-inflammability and its resistance to oxidation, ozone and weathering are said to make this unusual elastomer applicable to advancing technology in the aircraft, missile, automotive and chemical industries. Minnesota Mining & Manufacturing Co.

EMD 1402 for further information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Sintered Nylon

Nylasint parts are formed by cold pressing and sintering crystalline nylon powders alloyed with inorganic additives resulting in basic nylon components said to have superior mechanical and thermal properties.

Controlled porosity to absorb and retain substantial quantities of oil is claimed to result in reduced static and running friction, increased wear resistance, elimination of contact corrosion and permanent built-in lubrication. Polypenco Ltd.

EMD 1403 for further information

Self-adhesive Label Holders

Presson is a transparent label holder that is said to stick to any clean, flat surface—steel, glass, wood, plastics, etc., without damage. It is claimed that it will remain in position indefinitely and when it is no longer required either the label or the transparent holder can easily be removed and re-used. In use a message can be typed, stencilled or written on card, which is inserted into the unit and cut to required size with scissors. Brown paper covering is removed and the unit pressed firmly to any clean surface. Precision Components (Barnet) Ltd.

EMD 1404 for further information

Pressure Regulators

A new range of standard and relieving-type pressure regulators for air and non-corrosive gases is said to show many new features, among which is a greatly improved accuracy over a wider operating range. This is coupled with greater accuracy of regulated pressure, even with widely fluctuating line pressure and rapidly varying flow, and with greater air capacity in terms of c.f.m. These improvements have been brought about by (1) balanced valve construction; (2) greater effective diaphragm area; (3) improved baffle and syphon design; (4) larger passages; and (5) larger valve openings.

Additional features include large filter screen enclosing valve as protection against dirt, choice of standard or relieving regulating springs, and simplified maintenance, as the unit can be completely dismantled without removing from line and access to valve parts is by hand-removable valve-guide plugs. C. A. Norgren Ltd.

EMD 1405 for further information

Pressure-reducing Valves

A new range of pressure-reducing valves, in sizes from ½ in. to 2 in. (known as type "470"), can be applied to steam, gas, air or liquid services, and are said to be of an extremely simple yet reliable design. The valves are generally constructed of heavy bronze castings, but the wearing parts, in all sizes, are made of stainless steel for longer life, and an integral strainer prevents the entry of dirt, scale or other foreign matter which would cause injury to the seating. Maintenance is therefore said to be negligible, yet, when necessary, easy to effect—an important consideration, as valves of this type are often under the control of operatives who are not skilled engineers. The spherical valve is practically self-cleaning and the metal seating is renewable. The valves are claimed to be suitable for upstream pressures up to 250 p.s.i. for steam or 300 p.s.i. for air or water, and operate at total temperatures up to 230 deg. C. The maximum downstream pressure is 150 p.s.i. for the ¼- and ⅜-in. sizes. Pressure alterations are made by simple screw adjustment. Samuel Birkett Ltd.

EMD 1406 for further information

Quick-release Coupling

A new quick-release fluid hose coupling, manufactured under licence from the Binks Manufacturing Co. of America, has been announced.

This compact coupling is said to be hard-wearing and its push-and-turn operation simple, quick and foolproof. It has important application in the motor industry, where it is said to have solved a major production problem caused by the enormous increase in the range of colours used today.

The principal advantages offered by the quick-release fluid coupling are, firstly, that it enables the operator to make a rapid change of colours, and, secondly, the gun can be disconnected for cleaning purposes without the necessity of "blowing back" or cleaning out fluid lines. A Bullows & Sons Ltd.

EMD 1407 for further information

Powder Couplings

These couplings operate via the medium of a dry fluid in the form of spherical heat-treated steel shot, and the amount contained in the housing is referred to as the "flow charge".

The housing or main body is fixed to the power input side of the coupling, and the hardened steel rotor, which is centrally located inside, is coupled to the output side, and both members are free to revolve independently of each other when the coupling is not in use.

When power is applied, the centrifugal force throws the charge in an outward direction, forming tightly-packed metallic rings between either side of the rotor and the perimeter of the housing. The rotor therefore becomes locked and achieves full load speed without slip and with 100 per cent efficiency. The amount of slippage before taking up the full load is dependent upon the maximum speed of the drive, diameter of the coupling and the weight of the flow charge. These factors can also be used to obtain slippage at a given overload, thus affording complete protection to the power unit.

The smooth power take-up is said to enable squirrel-cage electric motors to be used, thus rendering unnecessary motors with high starting torque characteristics and expensive switchgear. Powder Couplings Ltd.

EMD 1408 for further information

Oil-free Blower

A new and improved oil-free positive pressure blower has recently been added to the Alcosa range of fans, forges and furnaces. Made in a range of six sizes (Type H.S.P. up to 10 lb. pressure), these new models offer a maximum output of approximately 1,000 c.f.h. at 10 lb. pressure.

Light in weight, they are easily portable and, being vibrationless, need not be bolted down. When fitted with exhaust silencers they are said to be almost silent. Installation is easy, only simple wiring and pipework being required to put the units into operation.

The rotor is fitted with sliding blades made from a special non-metallic material which is claimed to give extremely long blade life. All parts are accurately machined and positioned to prevent contact between the rotor, cylinder and covers. A face-type seal prevents leakage past the shaft. William Allday & Co. Ltd.

EMD 1409 for further information

Electrical Tachometer

A new tachometer which can indicate the differential speed and identity of the faster of two shafts consists of a miniature three-phase alternator connected to a rectifier-type M.C. voltmeter. The alternator generates a voltage which is proportional to its speed and the voltmeter is calibrated in revolutions per minute, feet per second or any other required function of speed. There are no brushes or sliding contacts to cause wear. The use of three-phase is said to be an advantage over single phase, as there are three times as many voltage impulses per revolution and therefore the use of gearing for low-speed measurement can often be avoided. Crompton Parkinson Ltd.

EMD 1410 for further information

Clutch Unit

This new Mardrive unit, which uses a purpose-built Crompton Parkinson f.h.p. motor, is intended for use on high-speed coil winders, instrument lathes, conveyors, sewing machines, etc. As well as providing variable-speed facilities as part of its regular function, the new unit is said to give slow and very sensitive starting or extremely quick starting according to particular installation requirements.

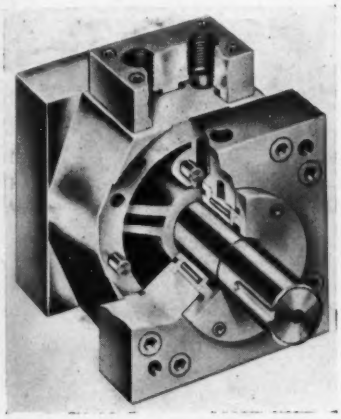
Outstanding characteristics claimed for the new clutch unit include low weight and compact design, a flywheel specifically designed to match the run-up torque and load factor of the motor, a completely detachable clutch and an adjustable control for rate of acceleration and braking. Marine Eng. Co. (Stockport) Ltd.

EMD 1411 for further information

Rotary Actuator

An agreement has been concluded to manufacture and sell in Europe and the U.K. the rotary torque actuator (Rotac) units of the Ex-Cell-O Corporation of America. The first to be made in this country will be the R.N. series. These are single- and double-vane units, fitted with needle roller bearings, and providing torque ratings from 1,500 in/lb. to 92,000 in./lb. at 1,000 p.s.i.

These compact, powerful units provide semi-rotary movement hydraulically controlled. The single-vane models allow



movement through an arc of 280 deg. The double-vane models develop much greater torque for the same pressure, but the arc of movement is restricted to 100 deg.

They are said to be specially useful where high power has to be provided in a small space. For automation equipment and machine tools they can be used in clamping, indexing, feeding, locating, transferring and turning over. They are also recommended for operating valves. Keelavite Hydraulics Ltd.

EMD 1412 for further information

Air Compressors

A new range of oil-cooled rotary compressors, called the Class R, has been developed for stationary electric operation, together with optional water cooling of the oil as an alternative to air cooling. The compressor consists of a simple vane-type rotor enclosed in a sealed compression casting.

The new range includes units with capacities of 100, 135, 160, 300 and 510 c.f.m. at a pressure of 100 p.s.i.

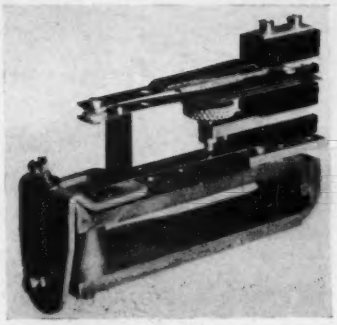
Specific features include a gradual unloading control to regulate compressor output, Vokes Micro-Vee type filters with cleaning device and squirrel-cage screen-protected motors with Star Delta starters for wall mounting. For mining service, plants are fitted with Teddington control panels and flameproof equipment is supplied where required in this respect. Further features include the use of Norgen automatic drain valves and a hand-operated starting valve. To build up when starting and to bleed off this pressure when closing down, an automatic service discharge valve is installed on the discharge end of the oil separators. Consolidated Pneumatic Tool Co. Ltd.

EMD 1413 for further information

Busbar Relays

A new relay, type BZ/R for round and BZ/SQ for square busbars, can be used to provide an indication of heavy current flowing—for example, weld current indication. The relay can also be used as an overload device to trip at a preset figure.

No conventional coil is employed, thus eliminating any possible failures through sustained overloads. A yoke is clamped around the conductor in a simple manner and in such a way as not to disturb the



existing installation. High quality Swedish iron is employed for the yoke and is said to avoid residual magnetism.

Each relay is provided with one set of normally-open 6-mm. silver contacts capable of handling 4 amp. at 250 volts a.c. and an adjusting screw enables the operating figure to be set within the ranges quoted for each type. Both types of relay are available (if required) with a pneumatic damper to provide approximately a half-second delay in operation so that high transient currents would not cause the relay to operate. Londex Ltd.

EMD 1414 for further information

Digital Indicating Instruments

A series of digital indicating instruments has been developed based on the E.T.L.-R.R.E. digital voltmeter. All utilise transistors and relays only and have a basic measuring sensitivity of 10μV. The output of each instrument is in binary coded decimal form, and integral translation to decimal form, with Digitron display, is provided in certain versions. Input power supplies are 100-125, 200-250 V., 40-50 c.p.s. in each case and performance is maintained over mains changes of from +5 per cent to −10 per cent of nominal. Digitising may be initiated manually or by external positive or negative pulses or contact closures and is completed within approximately one second. Standardisation facilities are provided on each instrument. Ericsson Telephones Ltd.

EMD 1415 for further information

New Publications and Technical Literature

Aluminium Union Ltd.: *Aluminium for Insulated Cables.* Reviews in detail the uses and advantages of aluminium as a substitute for copper or lead in cables.

EMD 1416

Apex Construction Ltd.: Leaflet describing revised range of small-scale equipment for chemical engineering departments of universities and colleges.

EMD 1417

Birlec Ltd.: Publication No. 705, giving details of newly-developed range of nitrogen generators.

EMD 1418

Bakelite Ltd.: 1959 edition of *Plastics Review* highlights some of the current applications of the company's plastics in industry and in the home.

EMD 1419

British Aluminium Co. Ltd.: Booklet dealing with self-adjusting arc welding of aluminium and its alloys.

EMD 1420

British Steel Founders Assoc.: *Distinctive Characteristics and Properties of Products in Cast Steel.* Reprint of a French article on this subject.

EMD 1421

Clayton Dewandre Co. Ltd.: Brochure dealing with the range of rotary exhausters, including new developments.

EMD 1422

Crofts (Engineers) Ltd.: New series of brochures, including those dealing with timing belt drives, magnetic clutches and brakes and emergency slipping devices.

EMD 1423

Crompton Parkinson Ltd.: Folder describing the repair and renovation service for f.h.p. motors.

EMD 1424

Dowding & Doll Ltd.: Brochure describing the V.4 hobbing machine for producing smaller gears.

EMD 1425

Fischer & Porter Ltd.: Six-page booklet containing correction factor curves for Flowrators.

EMD 1426

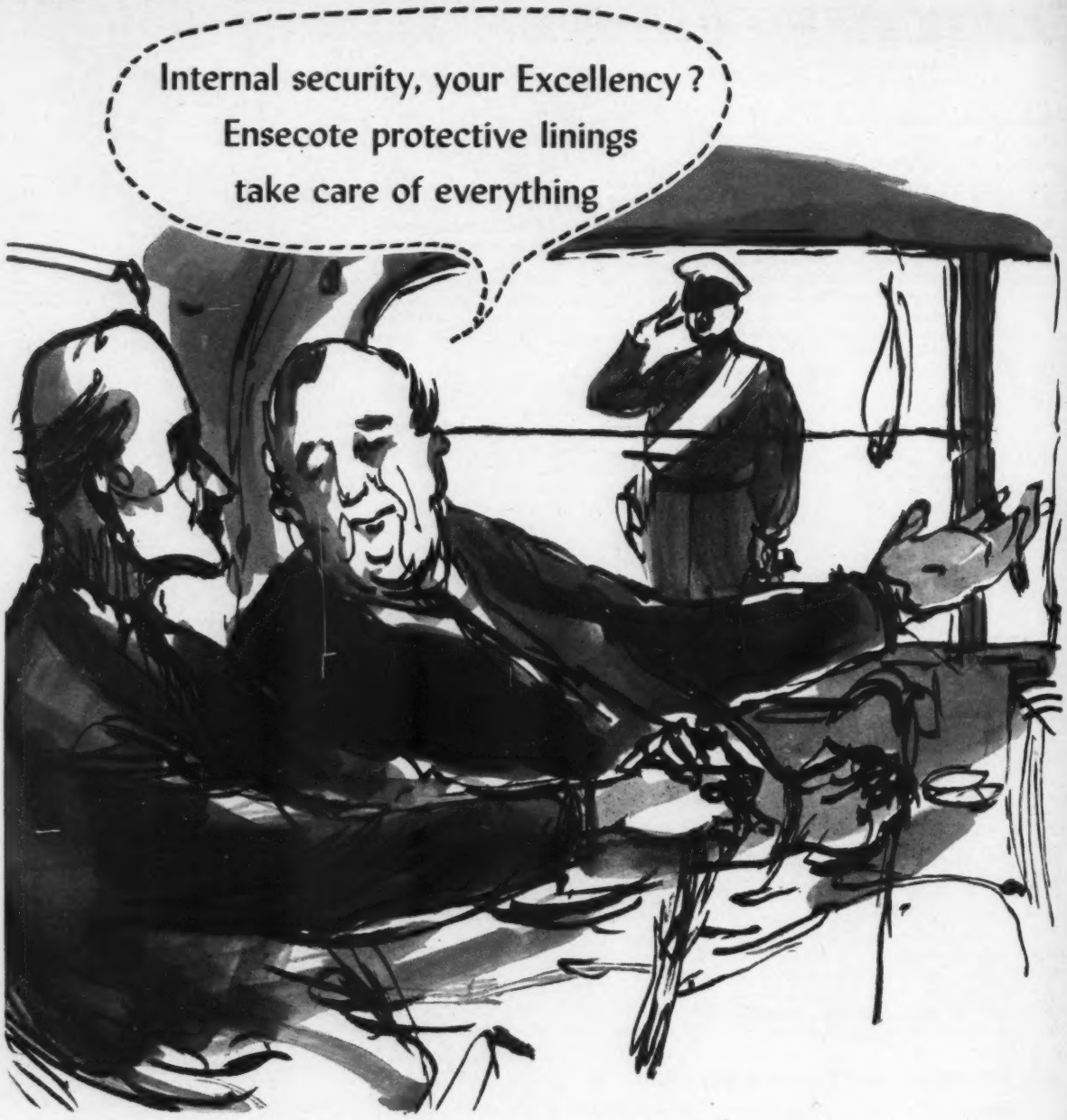
Furnival & Co. Ltd.: Colour brochure describing the new Giant range of guillotines.

EMD 1427

Hellerman Ltd.: First of a bi-monthly news sheet featuring new or modified products.

EMD 1428

EMD 1324 for further information



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News of Industry

Concast A.G. of Zürich, in which the United Steel Companies have recently acquired shares, is currently carrying out work on the development of the horizontal, continuous casting of steel. Two machines have been constructed and a third is soon to be put into operation. The process is claimed to have already been proved commercially in the production of non-ferrous metal billets.

Lewis Spring Co. has now moved to new premises in Studley Road, Redditch.

The formation of the **British Association of Corrosion Engineers** was announced in London last month. Its initial aims are to develop social and technical contacts among members, but it is intended eventually to establish suitable qualifications for corrosion engineers and standardisation of terminology and techniques. Its address is 97 Old Brompton Road, London, S.W.7.

At the recent opening of a new laboratory at Tipton by **British Rolling Mills Ltd.**, a plaque was unveiled to commemorate the first commercial beam engine built to the designs of James Watt in 1776 in that town.

New president of the **Institution of Engineering Designers** is Sir Myers Wayman, in succession to Lord Nuffield, who held the office for the past five years.

Substantial reductions in the price of wrought titanium are announced by **I.C.I.** Metals Division. Prices of sheet, strip, plate and wire are reduced by 25 per cent, rod and billet by 15 per cent and extrusions by 12½ per cent.

A new steelmaking process developed at **Brymbo Steel Works Ltd.**, near Wrexham, means that, for the first time on a major scale, molten iron from a blast furnace can be refined and charged directly into electric arc furnaces. In place of normal blast furnace metal containing about 0·6-0·8 per cent phosphorus which is insufficient to enable a basic converter to blow the metal to a workable temperature, a process of prerefining with oxygen was introduced, which is notably superior because it removes the silicon and phosphorus from the metal before decarburisation.

I.C.I. Plastics Division is to erect a new plant near Dumfries for the manufacture of Melinex polyester film. Only small quantities of the material have so far been produced in the U.K. Polyester film has crystal clarity, great mechanical and dielectric strength, as well as chemical and heat resistance.

A new Anglo-American company is being set up to specialise in the design, manufacture and marketing of remote-controlled nuclear handling apparatus. Announced jointly by Savage & Parsons Ltd. and General Mills Inc., it will be known as **Nuclear Equipment Ltd.**, with headquarters at Watford.

As part of a research programme into the causes of transformer noise, **Ferranti Ltd.** have recently completed a new anechoic chamber. The programme is a result of proposals by the Central Electricity Board and the B.E.A.M.A. that manufacturers should measure noise from transformers with a view to the eventual specification of maximum sound levels.

The **Council of Industrial Design** has appointed Mr. W. H. Mayall as industrial officer for the engineering industries, in succession to Mr. L. A. Grosbard.

A new modern laboratory devoted to development work on neoprene and other synthetic rubbers was opened recently by **Du Pont Co. (U.K.) Ltd.** at Hemel Hempstead. It will provide technical assistance to rubber manufacturers and processors in Europe, Africa, Australia and parts of Asia.

The **D.S.I.R.** has announced that a "creep information centre" is being set up at the National Engineering Laboratory at East Kilbride, where industrial designers can readily obtain data on the strength of high-temperature materials. Its main object will be to collect and tabulate all available data on creep and rupture properties. Data for British materials will be issued in an agreed form as far as considerations of commercial security will allow. All firms and research organisations concerned with such materials are invited to participate.

A new wide rolling mill is being installed by **Northern Aluminium Co. Ltd.** to provide aluminium plate as much as 10 ft. wide. It will come into service towards the end of next year.

A new factory was opened at Colchester recently by **Gamet Products Ltd.**, one of the Geo. Cohen 600 Group. It is devoted solely to the manufacture of taper roller bearings developed by Louis Gamet; a feature of the bearing is the adoption of hollow rollers held within a specially-treated light alloy cage, eliminating any tendency for the lubricating oil to be churned violently by centrifugal action. The accuracy of the system installed is such that bearing rings can be sized to within ±0·00005 in.

A gold medal in the engineering section of this year's International Inventors' Exhibition in Brussels has been awarded to Mr. I. M. Furnival, managing director of **I.G.E. Ltd.**, for his Masterotor automation control unit. The unit is designed to allow greater flexibility in the control of any number of circuits making and breaking at any point in the operating cycle of machine or process.

I.C.I. Ltd. has entered into an agreement with the Aluminium Co. of America (Alcoa) to collaborate in the manufacture of wrought aluminium products. The two companies plan to establish a new company to be known as **Imperial Aluminium Co. Ltd.**, to which I.C.I.'s present aluminium plants near Swansea will be transferred. I.C.I. will hold 51 per cent of the capital.

Shell Chemical Co. has set up three divisions to handle its activities in the three main fields of industrial chemicals, agriculture and plastics. Industrial chemicals will be concerned with solvents, general chemicals and resins; plastics will include polyolefins, polystyrene, p.v.c. and synthetic rubber.

Testing taper roller bearings on a Reicherter automatic Rockwell hardness-testing machine at the new factory of Gamet Products Ltd. (See story this page.)

A one-day symposium on the subject of spark machining is to be held at the Botanical Gardens, Birmingham, on September 16. Announcing this, the **National Association of Drop Forgers and Stampers** says that it will be mainly concerned with spark machining as a means of die sinking.

Further details from Technical Officer, Grove Hill House, 245 Grove Lane, Handsworth, Birmingham, 20.

The **British Iron and Steel Research Association** are planning two Open Days at their laboratories at Battersea Park Road, London, S.W.1, on October 22 and 23.

The second course in 1959 on the uses of radioisotopes, planned to suit the needs of company directors and executives, is being held at Harwell from September 29 to October 2. Intended to stimulate ideas among persons without any training in radioactivity, they provide an opportunity for **U.K.A.E.A.** research workers to make contact with industrialists who have specialist problems to solve.

The design, experimental and proving facilities of **Birfield Engineering Ltd.** are now concentrated at the Hardy Spicer premises at Chester Road, Birmingham 24.

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